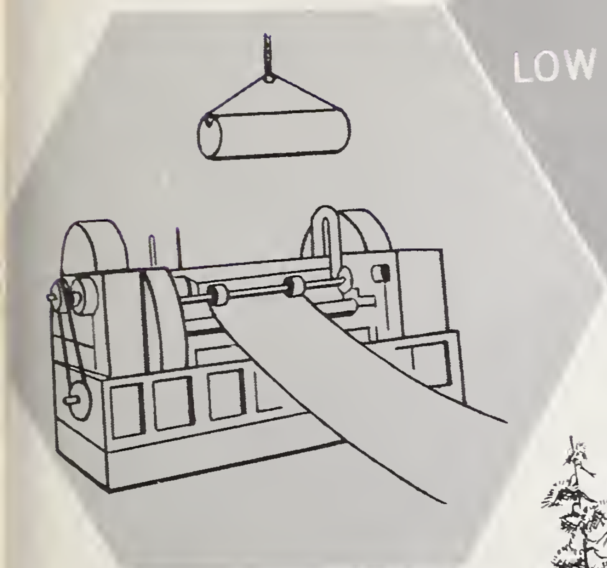
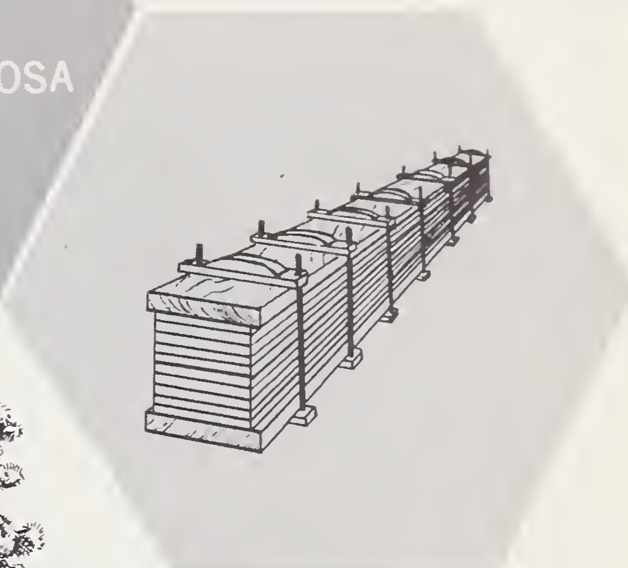
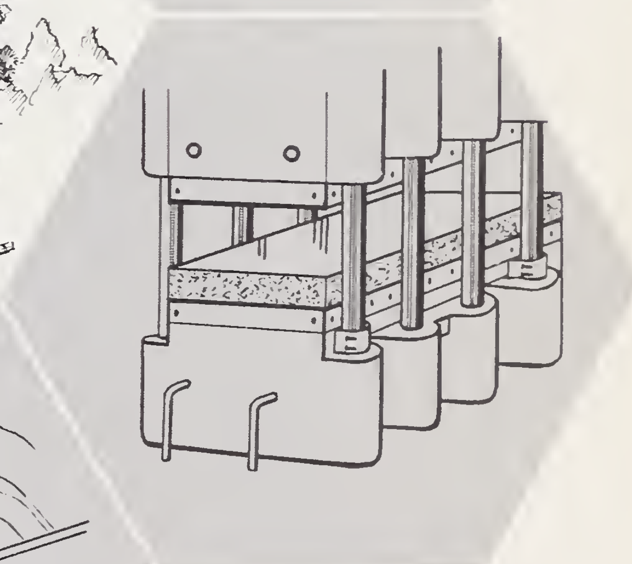
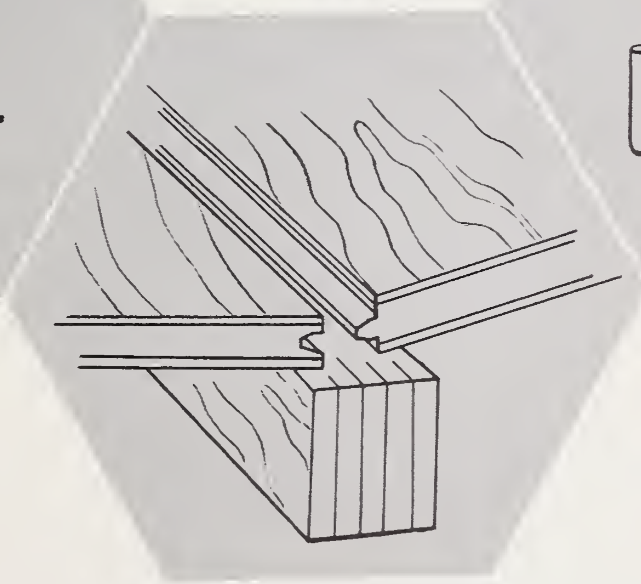
NEW PRODUCTS

FROM
LOW GRADE PONDEROSA
PINE TIMBER









U. S. FOREST SERVICE RESEARCH PAPER RM-10, DECEMBER 1964

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
and
FOREST PRODUCTS LABORATORY
FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE

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This study was made at the U.S. Forest Products Laboratory, Madison, Wisconsin, through collaboration of personnel of the Forest Products Laboratory, the Rocky Mountain Forest and Range Experiment Station, the Southwestern Regional Office of the Forest Service, and the Southwest Pine Association (affiliated with Western Pine Association).

Lincoln A. Mueller of the Rocky Mountain Station participated in the study. The industry representative most directly concerned with the work was A. C. Hunt of Southwest Forest Industries, Inc., who served as chairman of the industry liaison committee.

Forest Products Laboratory scientists bearing primary responsibility for specific phases of the program included:

Bruce G. Heebink, and John F. Lutz on initial survey, planning, scheduling, and coordination;

Bruce G. Heebink and Charles J. Gatchell on product engineering and design, overlaid products, particle board products, and specialized flooring products;

Richard F. Blomquist, Robert A. Hann, John F. Lutz, Chester Roessler, and M. L. Selbo on glues and glued products; and

Fred Werren, Edward W. Kuenzi, and Billy Bohannon on engineering tests and evaluation.

In addition, the advice and opinion of numerous other Forest Service scientists contributed significantly to the direction and development of the study.

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NEW PRODUCTS FROM LOW-GRADE PONDEROSA PINE TIMBER

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New Products from Low-Grade Ponderosa Pine Timber

by
Roland L. Barger and Herbert O. Fleischer

THE STUDY IN BRIEF

Low-quality ponderosa pine sawtimber poses severe economic problems for wood-product industries of the Southwest. Much of the material currently available is unsuited to the production of salable grades of lumber, historically the major product manufactured. Efficient utilization of the resource requires that this material be diverted to more suitable uses. A declining lumber market has further emphasized the need for product diversification in the region.

An intensive program of product research and development was proposed after a field survey and analysis of the problem in 1961. The program placed primary emphasis upon developing profitable uses for low-grade ponderosa pine timber. Products specifically suggested for evaluation included underlayment plywood, glue-laminated beams, overlaid siding, flooring, and particle board.

Product design, development, and evaluation studies were initiated at the Forest Products Laboratory in 1962, and were essentially completed in 1963. The research program has developed an array of light-construction products that can feasibly be produced from low-grade ponderosa pine timber. These products can be used individually in conventional construction, or can be combined as the integral components of a coordinated component building system.

This study deals specifically and in detail with the technical aspects of production--not with economic aspects. Technical feasibility alone is often not an adequate criterion for decision. It must be supplemented with economic evaluations of investment and production costs and of marketing opportunities. Some work in developing supplementary economic information is to be started in the near future. It should be recognized, however, that many economic considerations are peculiar to a particular firm or area, and not common to the industry as a whole. Consequently, a firm can perhaps benefit most from its own analysis of economic feasibility.

THE SOUTHWESTERN TIMBER RESOURCE

Ponderosa pine is an important commercial timber species in many western states. It is the major commercial species in the Southwestern region. Arizona and New Mexico contain almost 10 million acres of commercial forest land, supporting approximately 60 billion board feet of sawtimber (fig. 1). Ponderosa pine accounts for more than two-thirds of this volume (table 1).

Much of the ponderosa pine timber in the Southwest is in cutover stands, often exists under marginal growth conditions, and is of low quality for many conventional uses. Sawtimber currently available in the region characteristically includes high proportions of grade 5 and lower quality logs (fig. 2). A summary of cruise data from five recent southwestern timber sales indicates that over 80 percent of the logs offered for sale are of grades 4, 5, and 6 (table 2).[3]

[3] *Grades 4, 5, and 6 refer to those of the six-grade ponderosa pine log grading system developed by Pacific Northwest Forest and Range Experiment Station (PNW), Portland, Oregon.*

Figure 1.--Typical southwestern ponderosa pine sawtimber stand. Note heavy limbing characteristic of the species. Coconino National Forest, Arizona.

Most of the logs included in the "grade 4 and lower" category are of grades 5 and 6. Grade 4 logs are extremely rare in southwestern ponderosa pine forests because of the gap in the age class in trees that commonly yield grade 4 logs. When present, such trees are generally reserved for future cutting.

For most conventional products, knots are the primary limiting defect in southwestern ponderosa pine. Ponderosa pine tends to be somewhat open-grown and does not prune well naturally; consequently, most stems have numerous large, live limbs. The resulting log knots are generally firmly intergrown and do not loosen in the production of lumber. Most of these knots have large areas of short grain or irregular end grain associated with them, however, which potentially affect the strength of the entire piece. Dead, encased, and infirm knots are relatively rare in ponderosa pine, and are quite small when they do occur.

Table 1.--Volume of commercial sawtimber in the southwestern region

Species	State		Total
	Arizona	New Mexico	
	MM board feet		
Ponderosa pine	23,751	18,177	41,928
Douglas-fir	2,130	4,883	7,013
True firs	1,203	2,603	3,806
Engelmann spruce	778	3,495	4,273
Other softwoods	236	714	950
	28,098	29,872	57,970
Hardwoods	189	1,870	2,059
Total	28,287	31,742	60,029

Other common defects that can affect product potential to a lesser degree are lean (compression wood) and heart rot (Polyporus anceps Pk.). Leaning stems are common in southwestern ponderosa pine. It has been estimated that as much as 15 percent of the standing timber in some areas leans 5 degrees or more. Lean of 5 degrees is generally considered sufficient to develop objectionable compression wood.

Heart rot is most prevalent in old-growth timber, although it also occurs frequently in young stands. It is one of the major sources of scale deduction and product degrade.

The utilization of this low-quality timber creates technological and economic problems for a regional industry historically geared to single-product, lumber operations. Much of the saw-log material currently available is unsuited to profitable production of lumber. Lumber grade recovery from ponderosa pine in this region commonly includes as much as 40 percent grade 4 and 5 common lumber. These grades have never been more than marginal products, a situation aggravated by a depressed and declining lumber market. Since these grades of lumber make up an important part of total output, the economic impact upon industry is severe.

Figure 2.--Typical grade 5 (upper) and grade 6 (lower) ponderosa pine sawlogs.

Table 2.--Log grade distribution in five southwestern region timber sales

National Forest and unit	Log stand table, grade				Total
	1	2	3	4 and lower	
	Number of logs cruised				
Apache:					
Buckalou	49	94	130	723	996
Sitgreaves:					
Wiggins	5	20	81	503	609
Coconino:					
Harding Point	19	13	89	715	836
Santa Fe:					
Coyote	20	34	142	624	820
Apache:					
Black River	68	127	291	2,467	2,953
Total	161	288	733	5,032	6,214
	- - - - Percent - - - -				
Distribution	2.6	4.6	11.8	81.0	100.0

A PRELIMINARY SURVEY

In 1961, a team of Forest Service research personnel and regional industry representatives conducted a field survey and analysis of the problem. The survey verified the predominance of low-grade saw logs and lumber, and provided a basis for developing an applied research program.

Two factors were found to contribute to the overall utilization problem:

1. The quality of the timber common to the Southwest yields high proportions of the lower common grades of lumber. Much of this lumber will not return a profit.

2. Lumber, regardless of grade, is becoming a less profitable product. This is especially true for sheathing, subflooring, forming, and similar construction uses, upon which the lower common grades of lumber depend. Plywood and nonwood sheet materials have seriously encroached upon these former lumber markets.

Any program proposed to develop new products and alleviate current utilization problems must therefore concentrate upon products competitive with existing building products such as plywood, particle board, and laminated members. The program must also concentrate upon products which can either circumvent or tolerate the range of defects common to the timber involved. For southwestern ponderosa pine, the primary defect affecting product potential is the presence of numerous knots.

Housing and building construction provides the greatest potential market for wood products. Modifications are needed to create products that can compete effectively with other

types of building materials. A major inherent disadvantage of wood in lumber form is the excessive labor cost of application and, therefore, high installed cost. Panel products, combined-function products, and semifinished products can all decrease installed or finished costs.

The current trend in the light-construction industry is toward component construction and coordinated component building systems. Consequently, it is desirable to consider not only individual products, but a coordinated group of new or modified products--sheathing, siding, flooring, laminated members--that would fit into a component building system. Thus an extensive product research and development program was initiated. The research program included the development, demonstration, and evaluation of new or modified products from both low-grade lumber and low-grade timber. Products from low-grade lumber included overlaid siding, laminated products, and flooring. These products can utilize extremely knotty material in standard lumber sizes, through selective cutting, masking, and preassembly methods. The program also included veneer and plywood and particle board products, each capable of utilizing low-quality timber in forms other than standard lumber.

The products considered offered greatest apparent promise for low-grade timber utilization, and required minimal changes in existing mill facilities. The products also offer potential as a combined group that could form a coordinated component building system.

TEST MATERIALS

Test materials for the study were selected by industry and research personnel at sawmills in Arizona and New Mexico, and shipped to the Forest Products Laboratory. The materials were selected from the lower or "problem" grades of logs and lumber (fig. 3). The test lumber used was all of grades 3, 4, and 5 common, and all logs for veneer were of grade 5. In addition, a grade 6 log and low-quality slabs were included as chipping material for particle board. An itemized description of all ponderosa pine test materials used is presented in appendix A, page 51.

PRODUCT DEVELOPMENT, DEMONSTRATION, AND EVALUATION

Product research included designing specific construction products peculiarly suited to the low-quality wood resource, manufacturing these products on a prototype basis, and subjecting them to standard and improvised evaluation tests. This section of the report covers the rationale behind product design, production and testing procedures, and apparent technical feasibility for each of the specific products under study.

Veneer and Plywood

Plywood manufactured for specific uses which will tolerate defects common to low-grade ponderosa pine offers considerable utilization potential. Primary consideration has

Figure 3.--A group of grade 5 and 6 ponderosa pine logs provided as test material.

been directed toward underlayment plywood. Standard sheathing and subflooring products have not received active consideration for several reasons:

1. Commercial Standard specifications for any type of plywood will be difficult to meet when only low grades of logs are utilized. The underlayment market offers promise for a specialized product that need not conform to Commercial Standards.

2. Industry has indicated interest in producing a 4- by 4-foot panel, a size preferable from the standpoint of better utilization of low-grade material. This size is not objectionable in underlayment, and may offer some advantages, but may not be well accepted as standard construction plywood.

3. Competition in the general softwood construction plywood market is formidable. If such a product could be made, entry into the market might prove extremely difficult.

Underlayment plywood is conventionally used between subflooring and finish flooring of various tiles, carpeting, or other resilient flooring to provide a smooth, relatively joint-free base (fig. 4). As such, it does not require the strength or nail-holding properties of sheathing or subflooring. If large knots can be bonded well enough to prevent delamination in use, practically any size knot could be included in underlayment panels.

U. S. Commercial Standard CS 122-60[4] requires that interior underlayment plywood be constructed with a C-repaired face veneer and C second ply, and allows remaining veneers to be of D grade. This means that the second ply (grade C) can have open defects up to 1 inch in diameter, and all remaining veneers can have open defects up to 2-1/2 inches in diameter. A specialized underlayment plywood with no appreciable open defects in the upper three or four plies may therefore offer a distinct improvement over standard underlayment.

The product developed does not conform to Commercial Standard veneer grade specifications. In the test plywood, sound knots of any size were allowed in all veneers. Open defects were not allowed in any except the back, however, so the product had four sound plies.

[4] *U. S. Department of Commerce. U. S. commercial standard CS 122-60 for western softwood plywood. Ed. 4, 22 pp., illus. Effective Dec. 31, 1960; revised April 15, 1963.*

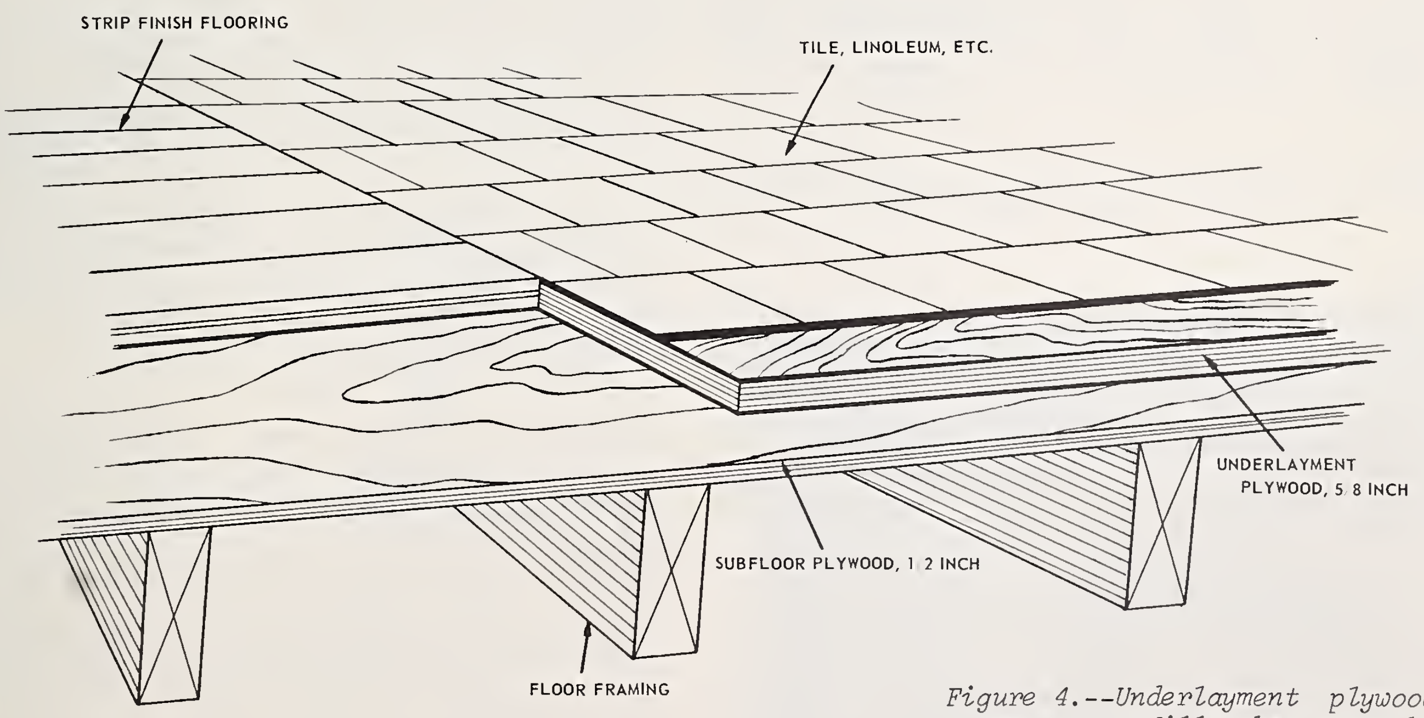


Figure 4.--Underlayment plywood acts as a filler between subflooring and finished flooring.

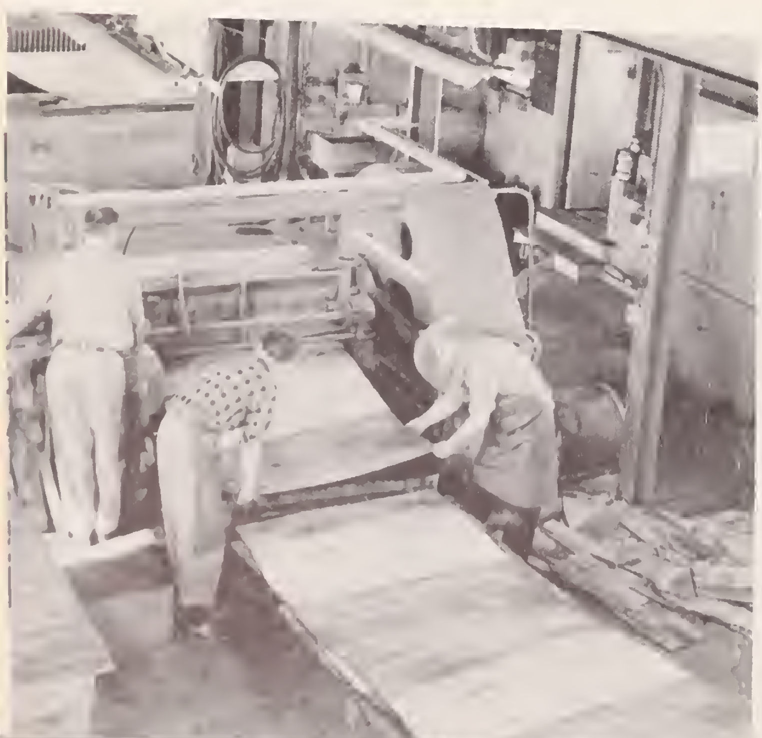
Veneer production

Two thicknesses of veneer were desired: one suitable for five-ply touch-sanded underlayment panels 5/8 inch thick, and one suitable for lumber-core laminated flooring panels. For the underlayment plywood, drying shrinkage, hot-press compression, and touch sanding were estimated to require a combined allowance of 0.090 inch. This allowance, plus desired finished panel thickness of 0.625 inch, required a green veneer thickness of 1/7 inch (0.143).

The lumber-core laminated flooring panels, discussed at length later in the report, were designed to require back and face veneers approximately 1/4 inch thick (0.235 inch minimum for a panel thickness of 1-1/4 inches). It was anticipated that the thicker veneer would cut less smoothly, and would require greater sanding allowance to provide a suitable finished surface. A minimum allowance of 0.050 inch in veneer thickness was estimated for drying shrinkage, cold-press compression, and sanding. Accordingly, all veneer cut for use in lumber-core panels was cut 3/10 inch thick (0.250 + 0.050).

Four grade 5 saw logs were provided for conversion into veneer (see fig. 3). Eight 52-inch test bolts were cut from the four 10-foot logs, one bolt from each log designated for 1/7-inch veneer, the other for 3/10-inch veneer. The test bolts are described in appendix A, table 18.

Figure 5.--Veneer is cut from a 4-foot peeler bolt on a rotary veneer lathe.



The four bolts designated for 1/7-inch veneer were heated under water at 140° F. for 60 hours or more. The bolts designated for 3/10-inch veneer were heated for a similar period of time at 160° F. Prior veneering tests had indicated that the higher temperature was desirable for cutting thick veneer, although it may induce end splitting in the bolts. All bolts heated at 160° F. developed heartwood splits during heating; the splits were confined to the core portion of the bolts, however, and did not affect recovery.

The heated test bolts were debarked, inspected again for noticeable defect, and converted to veneer on a 4-foot rotary veneer lathe (fig. 5).

Lathe knife and pressure bar settings used in cutting the veneer (fig. 6) are shown in table 3.

Some preliminary veneer runs were made with horizontal pressure bar openings of 0.128 for 1/7-inch veneer and 0.285 for 3/10-inch veneer. These settings appeared to exert more pressure against the bolt than necessary. Less shelling was experienced by allowing 0.005 inch greater horizontal clearance (0.133 and 0.290, respectively).

All veneer cut smoothly with the exception of bolts 3-1 and 3-2, which contained wide bands of compression wood. The compression wood caused a comparatively rough cut, and caused some shelling in the 3/10-inch veneer, but did not result in the loss of any veneer.

All test bolts except one were cut without difficulty with 6-inch chucks through the entire cutting process. Bolt 5-2, the largest bolt from which 3/10-inch veneer was cut, required 8-inch chucks.

The green veneer was clipped to remove roundup, wane, and other inadmissible defects, and was clipped to rough panel widths where possible. The green veneer was measured for total green recovery, but was not graded. The veneer was dried in a conventional steam-heated continuous roller dryer. The average time and temperature required to adequately dry heartwood and sapwood veneer of both thicknesses is indicated in table 4.

Table 3. --Veneer lathe adjustment

Bolt number	Desired veneer thickness		Knife angle	Pressure bar		
	Green	Finished		Bevel	Vertical opening	Horizontal opening
	Inches	Inches	Degrees-minutes		Inches	Inches
2-2, 3-1, 4-1, 5-1	0.143	0.125	89°50'	15°	0.028	0.133
2-1, 3-2, 4-2, 5-2	.300	.250	89°40'	15°	.030	.290

The 1/7-inch veneer was dried without difficulty (fig. 7). Sheets containing bands of compression wood buckled only slightly. All intergrown knots remained intact in the dry veneer, while most encased knots fell out during drying. Since there were relatively few encased knots, a high recovery of solid veneer was obtained.

The first run of 3/10-inch veneer was dried in a single pass through the dryer. Much of the veneer developed severe end splits, which progressed into the sheet as much as 12 inches. It was believed that the splitting could have resulted from the rather long period of continuous exposure to high temperature and excessively rapid drying from the ends of the thick veneer.

In an attempt to prevent or minimize end splitting, the second run of 3/10-inch veneer was dried in two or more passes through the dryer (table 4). In addition, 1-1/2 inch kraft-type tape was applied to both ends of each

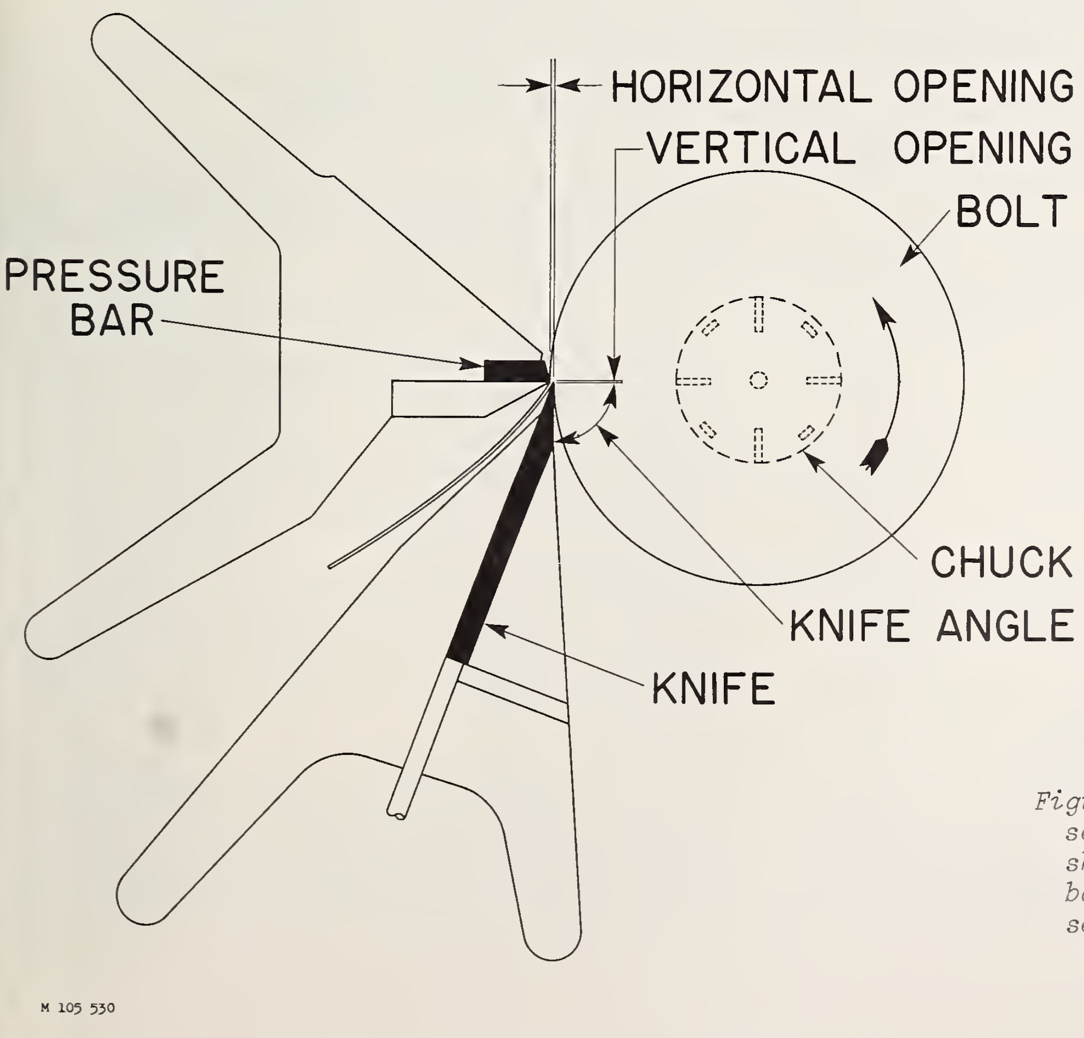


Figure 6.--Diagrammatic cross section of a veneer lathe, showing position of pressure bar and knife, and associated settings.

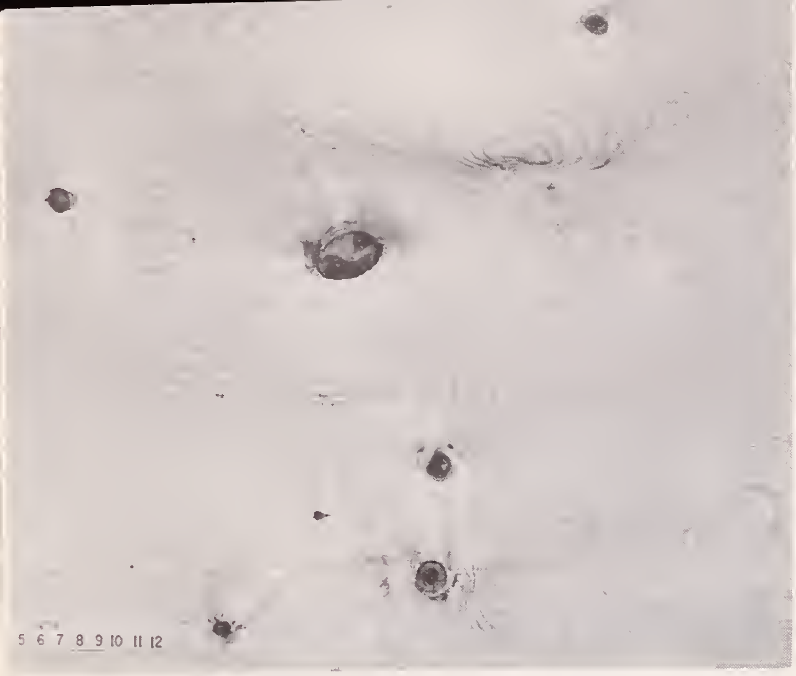


Figure 7.--Dry 1/7-inch veneer had relatively few open defects.

full-size sheet, on the tight side of the veneer. The tape performed dual functions of retarding end drying and mechanically restraining the veneer from splitting. The veneer so treated was successfully dried without appreciable end splitting (fig. 8). The combination of taping and multiple-pass drying was apparently effective in preventing splitting, although the relative effectiveness of the two treatments is not known.

Table 4. --Veneer drying time

Type of veneer and thickness	Temperature	Drying time	Final moisture content
	Degrees, F.	Min.	Percent
1/7-inch:			
Sapwood	310	18-19	2- 8
Heart and sap	310	18-19	2- 6
Heartwood	310	9	1- 2
3/10-inch, single pass:			
Sapwood	310	46	4-10
Heart and sap	310	46	3- 7
Heartwood	310	27	2- 6
3/10-inch, multiple pass:			
Sapwood--			
First pass	310	20.5	--
Second pass	310	20.5	4-30
Third pass	310	3	4-10 (final)
Heart[1] and sap--			
First pass	310	20.5	--
Second pass	310	20.5	3- 9 (final)

[1] All heartwood contained some inner sapwood, and thus required an intermediate drying time.

All dried veneer was remeasured and graded twice, by the two following grading systems:

1. Commercial Standard grades:
   (A) Essentially clear.
   (B) Clear, with rough grain.
   (C) Knots, 1-1/2 inches; knotholes, 1 inch maximum.
   (D) Any knot; knotholes, 2-1/2 inches maximum.

2. Improvised grades, suited to the segregation of sound knots from open defect:
   (a) Clear material.
   (b) Sound knots up to 1-1/2 inches in diameter.
   (c) Sound knots over 1-1/2 inches in diameter.
   (d) Open defect, patchable with conventional veneer patches.
   (e) Open defect, nonpatchable.

The minimum width considered in grading by either system was 6 inches.

Tables 5 and 6 show total veneer recovery, manufacturing losses, and dry veneer by grade for each grading system.

The Scribner Decimal C log rule is commonly employed to measure saw-log volume in the Southwest. It is, therefore, of some interest to compare product recovery with the Scribner Decimal C scale of the logs and bolts used in the study. Table 7 presents log and bolt scale, and dry veneer recovery after final grading and inspection. Veneer recovery is shown in square feet, in board-foot units of 144 cubic inches, and in terms of equivalent 3/8-inch plywood.

In computing a plywood-recovery factor based on Scribner log scale, it should be noted that the trim loss shown in column three would not ordinarily be incurred in commercial operation. This trim loss was

Figure 8.--The heavy 3/10-inch veneer dried without appreciable end-splitting, and practically all knots remained intact in the dry veneer.

Table 5.--Veneer manufacturing losses and total recovery

Bolt number	Veneer thickness		Veneer loss		Green veneer recovery	Drying loss	Dry veneer recovery
	Green	Average dry	Round-up	Green clip			
	Inches		- - - - - - -	- - - - - - -	Lineal inches	- - - - - - -	- - - - - - -
2-2	1/7	0.138	[1] 332	90	1,488	80	1,408
3-1	1/7	.138	162	8	688	50	638
4-1	1/7	.138	196	44	1,222	103	1,119
5-1	1/7	.138	182	[2] 207	2,066	164	1,902
Total			872	349	5,464	397	5,067
2-1	3/10	.292	180	60	833	33	800
3-2	3/10	.292	85	9	303	17	286
4-2	3/10	.292	97	8	617	37	580
5-2	3/10	.292	[3] 216	17	729	34	695
Total			578	94	2,482	121	2,361

[1] Includes loss of 78 inches due to chuck change.
[2] High green clip loss due primarily to intergrown bark pocket and mismanufacture (chip gouge).
[3] High round-up loss due primarily to chuck slipping, and subsequent change to larger chuck.

Table 6.--Veneer grade recovery

Bolt number	Green veneer thickness	Grade recovery					Cull	Dry recovery, cull excluded
	Inches	Lineal inches					Lineal inches	
		COMMERCIAL STANDARD GRADES						
		A	B	C	D			
2-2	1/7	0	24	297	1,087		0	1,408
3-1	1/7	110	0	303	200		25	613
4-1	1/7	31	0	273	799		16	1,103
5-1	1/7	571	0	255	1,073		3	1,899
Total		712	24	1,128	3,159		44	5,023
2-1	3/10	0	0	0	800		0	800
3-2	3/10	0	0	89	194		3	283
4-2	3/10	13	0	0	500		67	513
5-2	3/10	390	0	20	282		3	692
Total		403	0	109	1,776		73	2,288
		IMPROVISED GRADES						
		a	b	c	d	e		
2-2	1/7	0	311	1,056	41	0	0	1,408
3-1	1/7	111	304	168	34	0	21	617
4-1	1/7	37	254	290	509	11	18	1,101
5-1	1/7	562	228	855	201	53	3	1,899
Total		710	1,097	2,369	785	64	42	5,025
2-1	3/10	0	0	653	110	37	0	800
3-2	3/10	0	63	184	36	0	3	283
4-2	3/10	13	0	323	132	86	26	554
5-2	3/10	404	6	274	8	0	3	692
Total		417	69	1,434	286	123	32	2,329

due to the length of the test logs, and should be deducted from log scale before computing recovery factors. A valid overall recovery factor for the group of test logs can be computed as

$$\frac{\text{3/8-inch plywood recovery}}{\text{log volume, minus trim loss}},$$

$$\text{or } \frac{1156}{540-67} = 244$$

The recovery factor of 2.44 square feet of 3/8-inch plywood per board foot of log volume, Scribner Decimal C scale, compares favorably with recoveries commonly experienced in commercial softwood plywood production.

As is evident in the grade recovery shown in table 6, a relatively large proportion of the 1/7-inch veneer recovered had no appreciable open defect. A product, such as underlayment,

Table 7.--Study log and bolt volume, and associated veneer recovery

Log No.	Volume, Scribner, Decimal C	Trim loss[1]	Bolt No.	Volume, Scribner, Decimal C	Dry veneer recovery			Equivalent[3] 3/8-inch plywood
					Thickness	Quantity	Volume[2]	
	Bd. ft.	Bd. ft.		Bd. ft.	Inches	Sq. ft.	Bd. ft.	Sq. ft.
2	170	21	2-1	78	0.292	289	84.3	193
			2-2	71	.138	508	70.0	169
3	60	7	3-1	27	.138	221	30.5	74
			3-2	26	.292	102	29.8	68
4	120	15	4-1	53	.138	398	54.9	133
			4-2	52	.292	185	54.1	123
5	190	24	5-1	84	.138	686	94.5	229
			5-2	82	.292	250	72.9	167
Total	540	67	--	473	--	--	491.0	1,156

[1] Loss shown was incurred in cutting 10-foot test logs into 52-inch bolts.
[2] Actual dry recovery, in board-foot units of 144 cubic inches.
[3] Based upon nominal veneer thicknesses of 1/8 inch and 1/4 inch.

which requires a high proportion of sound, but not necessarily clear veneer, can therefore capitalize upon this inherent quality. In view of the high recovery of sound veneer, it was considered feasible and practical to limit open defect in the final product to the fifth or back ply only. The resulting panel is of considerably higher quality, with respect to open defect, than is normally produced under Commercial Standard specifications.

Panel layup and manufacture

Preliminary gluing trials were conducted to determine which adhesive systems would be suitable for underlayment panel construction, and the extent to which knots might interfere with the process. Twenty-four small three-ply test panels were fabricated from 1/8-inch veneer. Three adhesives--a hot-press blood-soybean blend, a cold-press soybean, and a hot-press exterior-type phenolic adhesive--were compared. The soybean and blood-soybean blend glues are interior-type glues. Other variables investigated included the effect of heartwood and sapwood, and the size and location of knots in the different plies.

Test specimens were subjected to standard shear and delamination tests. All test panels passed cyclic delamination test requirements for interior softwood plywood.[5] Average strengths and wood failures for dry shear specimens cut from the panels are shown below:

Adhesive	Dry shear strength (P.s.i.)	Wood failure (Percent)
Phenolic	220	90
Blood-soybean	211	48
Soybean	204	62

Some difficulty was experienced initially in obtaining uniform glue spreads over knotty areas. When care was taken in spreading glue, however, knots and knotty material posed no particular problems.

Blood-soybean adhesive proved superior in some respects (notably wet shear strength) to the soybean interior adhesive used. It was, therefore, adopted for use in producing demonstration underlayment panels.

[5] *For cyclic delamination test specifications, see footnote 4, p. 5.*

The 1/7-inch veneer was sorted into face, core, crossband, and back material. All veneer with appreciable open defect was placed in crossband and back stock. All veneer was clipped to 50-inch lengths, and full sheets were clipped to 50-inch widths. Fourteen 50- by 50-inch five-ply panels were laid up from the veneer, which fully utilized all 1/7-inch veneer. Open defect in face veneer was limited to splits or knot checks no more than 1/16 inch in width. Open defect in crossband and core material was limited to splits and checks not exceeding 1/16 inch in width, and circular open defects not exceeding 1/4 inch in diameter. Material with larger open defects was either clipped to provide sound crossbanding, or was utilized as back veneer. Two panel faces were patched with conventional boat patches, primarily to demonstrate the possibility of patching.

No difficulty was encountered in laying up panels with four essentially sound plies. The requirement for sound veneer thus imposed did not hinder complete utilization of the veneer available. A total of 498 linear inches of veneer, or approximately 13 percent of dry footage, was lost at the clipper in laying up the 14 panels. Of this, one-third was lost in sizing full sheets and two-thirds was lost in clipping open defect from crossband material.

The veneer loss sustained in laying up the panels is subject to some qualification. Very little defect was clipped from the green veneer. Defect that appeared to offer any chance for utilization was allowed to remain in the veneer through the drying process. Consequently, some of the clipping loss incurred in panel layup would probably have been clipped from the green veneer in a commercial operation. Also, much of the lost veneer could have economically been patched with efficient commercial patching equipment.

The plywood panels were fabricated with blood-soybean adhesive at a spread of 44 pounds per M square feet of single glue line. All adhesive was applied by double spreading crossband veneer in a double-roll spreader. The panels were hot pressed at a press temperature of 240° F., a pressure of 150 pounds per square inch, and a cycle time of 15 minutes (fig. 9). The panels were hot stacked upon removal from the press (fig. 10).

Thermocouples were placed in the interior glue lines of the first two panels pressed to determine interior glue-line temperatures. The temperature reached 200° F. in 5 minutes, and attained a maximum of 230° F. during the 15-minute pressing cycle. This is considered an adequate exposure to heat for complete curing of all glue lines.

Five-ply test specimens from three panels were subjected to soak-dry delamination tests and shear tests. In addition, one panel was sectioned into 6-inch squares to evaluate glue-line integrity and panel quality. All specimens performed satisfactorily and exceeded Commercial Standard requirements for interior plywood. Again, knots glued without difficulty, exhibited good glue-line integrity, and posed no problems.

The completed plywood panels were trimmed to 48-inch squares. The panels averaged 0.655 inch thick, which left an average sanding allowance of 0.030 inch to bring the material to standard 5/8-inch thickness.

Three panels were trimmed to 42 inches in width, to facilitate test sanding on a two-drum oscillating sander. First and second sander drums carried 1/2-60 grit closed coat garnet and 2/0-100 grit closed coat garnet, respectively. The high pitch content of the ponderosa pine panels caused rapid plugging of the closed coat paper; otherwise, no difficulty was encountered in sanding the panels to 5/8-inch thickness. The resulting touch-sanded surface was fully satisfactory for the intended use. Excessive paper plugging could be avoided by using open coat papers and wide belt sanders.

It appears that the green veneer thickness of 1/7 inch (0.143 inch) is correct for the 5/8-inch underlayment. The resulting panel thickness allowance is just sufficient to provide for drying shrinkage, hot-press compression, and adequate sanding.

Plywood evaluation

The test sample of eight veneer bolts is an insufficient basis for obtaining reliable veneer recovery information. The study logs selected, however, represented the range of sound de-

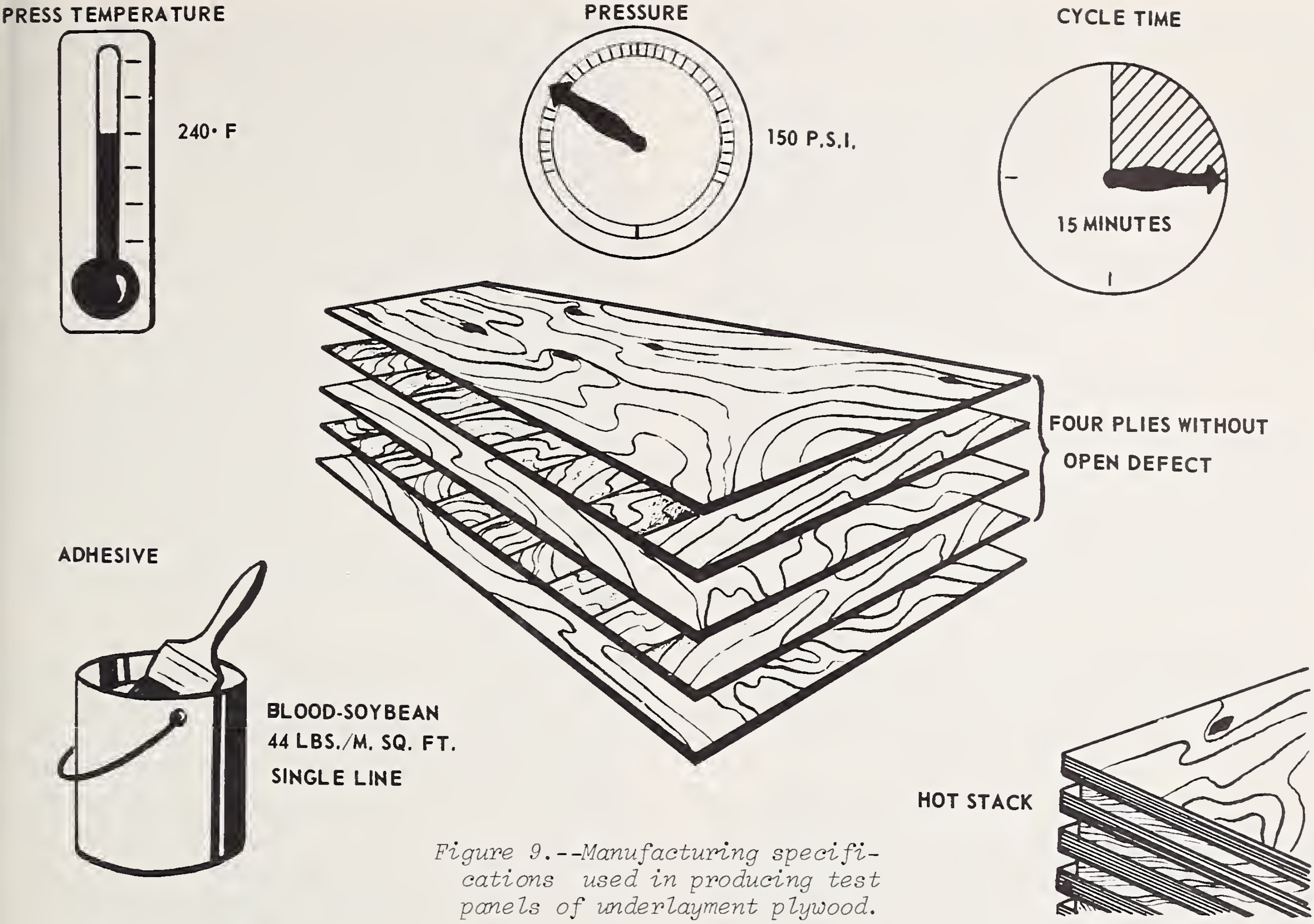
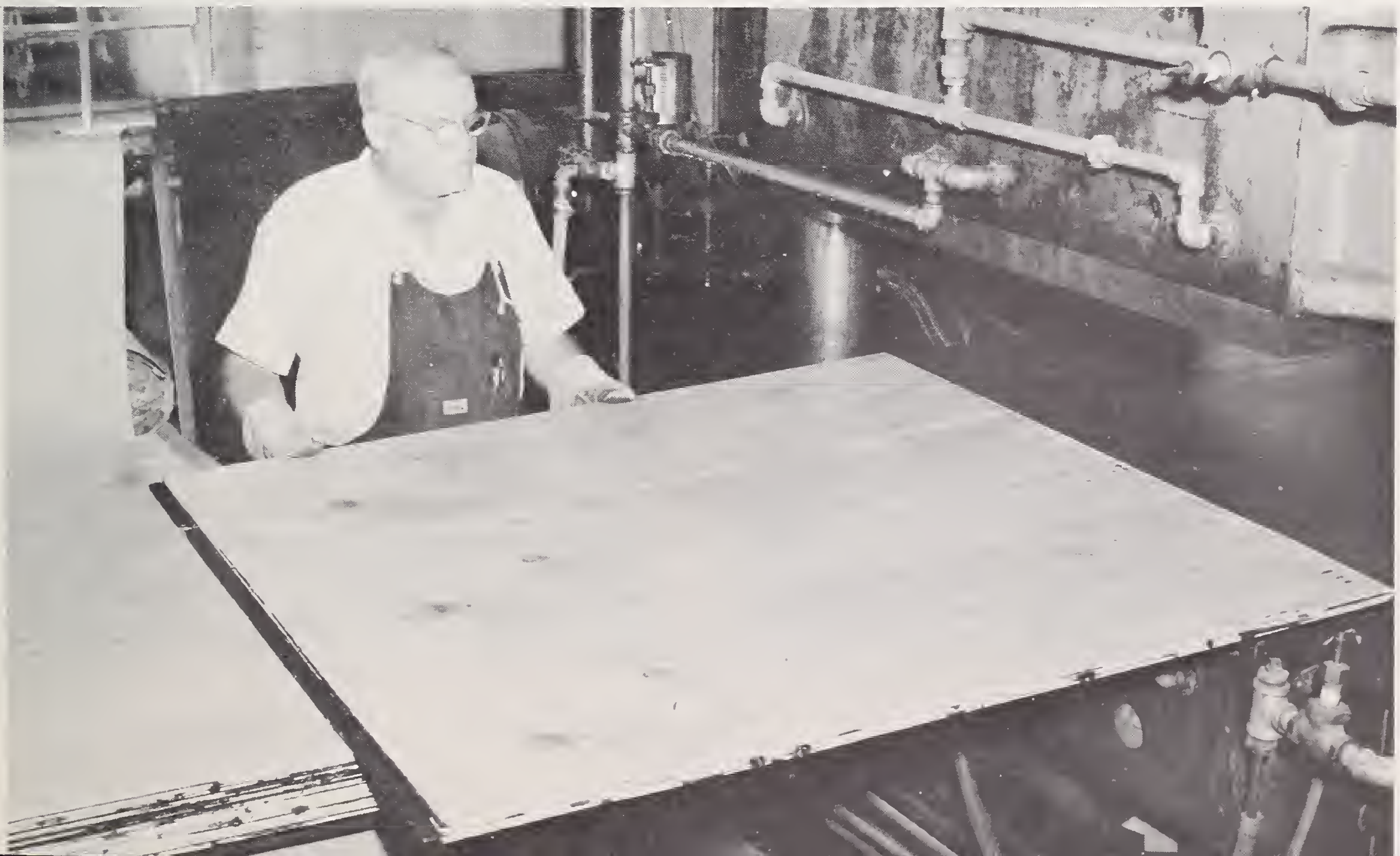


Figure 9.--Manufacturing specifications used in producing test panels of underlayment plywood.

Figure 10.--A 4-foot test panel of five-ply, 5/8-inch ponderosa pine underlayment plywood is removed from the press and hot stacked.



fect commonly encountered in grade 5 saw logs. Two of the study logs were more nearly representative of the low side of the grade. Consequently, the veneer grade and quantity recovery experienced in this study is probably below that which could be obtained commercially from a mixture of peeler logs including some logs of higher grade.

Although all test bolts contained numerous knots, more than 80 percent of the 1/7-inch veneer recovered was sound (see table 6). A product requiring a high proportion of sound, but not necessarily clear, material appears to offer the best utilization opportunity. The proposed underlayment plywood can capitalize upon the high proportion of sound veneer. In addition, since underlayment is a nonstructural application, stiffness and strength deficiencies will not limit its use. Compensating additional thickness and shorter span requirements common to load-bearing structural uses will be avoided. No strength or stiffness tests were made on these panels.

Primary consideration has been given to utilizing 4-foot peeler material and constructing 4- by 4-foot panels. The 4-foot or 52-inch veneer bolt offers substantial advantages in maximizing recovery from smaller, low-quality, rapidly tapering timber. The common practice of logging saw logs in multiples of 4 feet also coincides well with 4-foot bolt utilization. The equipment required to handle and process 4-foot veneer and panels is smaller and entails less capital investment. Product recovery, however, remains the major important advantage. In the smaller, low-grade timber under consideration, utilizing standard 8-foot veneer bolts could be expected substantially to lower net-product recovery.

In considering 4- by 4-foot panel production, an underlayment product again appears to have advantages. Longitudinal expansion and contraction in underlayment panels tend to "open" the joints between panels, and occasionally cause the joint to show through tile or linoleum. The joints between 4-foot panels will open less, due to the shorter panel length.

Strength and stiffness tests on laminated lumber-core flooring, discussed in detail in a later section of the report provide some idea of the strength characteristics of knotty veneer. They indicate that numerous large knots in the veneer materially lower the strength and stiffness of the final product, primarily because of the large areas of short grain associated with the knots.

Average stiffness of the veneer used in the flooring was only 70 percent of that expected for the species, and modules of rupture was approximately one-third of the average for the species. Brash tension failures in the areas of steep grain further indicate that impact strength would be low. The results of the tests lead to the conclusion that plywood constructed from knotty ponderosa pine veneers may not perform well in load-bearing structural uses, unless thickness or span compensations are made.

Commercial Standard CS 259-63,[6] which sets forth the commercial specifications for southern pine plywood, limits sound knot size in grade D panel backs to 2-1/2 inches in diameter. This limitation has been prescribed because of the known effect of knots and surrounding short grain upon load-bearing qualities. A similar limitation applied to ponderosa pine veneer used in structural grades of plywood might insure satisfactory strength and stiffness properties.

If a better "grade mix" of logs were used in manufacturing ponderosa pine plywood, sheathing grade specifications could undoubtedly be met. The plywood should then be fully adequate for structural diaphragm uses such as wall sheathing and soffits. Commercial Standard CS 122-60 groups the western softwoods, other than Douglas-fir, into three groups according to their relative stiffness. Ponderosa pine is included in group 3, the lowest. It is subject, therefore, to the limitations in structural use imposed upon group 3 softwoods.

FHA minimum property standards[7] allow the use of groups 2 and 3 softwood plywoods

[6] *U. S. Department of Commerce. Commercial standard CS 259-63, southern pine plywood. 1963.*

[7] *U. S. Federal Housing Administration. Minimum property standards for one and two living units. Fed. Housing Admin. Pub. 300, Rev. 4. May 1963.*

that meet Commercial Standard specifications as underlayment (nonstructural), subflooring, wall sheathing, and roof sheathing. When used as roof sheathing or subflooring, however, compensating additional panel thickness or shorter support spans must be used. Compensating thickness or span dimensions are not required for underlayment and wall sheathing uses, since they are nonload bearing in nature.

Use standards, however, are based upon average characteristics of the species. As previously mentioned, load-bearing strength of veneers from low-grade ponderosa pine appears to be far below average for the species. Consequently, practical uses of sheathing-grade plywood made from veneers containing many large knots are probably limited to nonload-bearing applications. The range of potential use for sheathing-grade ponderosa pine plywood will depend heavily upon the quality of timber being utilized. This factor should receive careful consideration when production of a sheathing-grade product is considered.

Particle Board

Particle-board manufacture may offer a means of utilizing logs that are too small or too rough to be of value in the manufacture of boards or veneer. In addition, much sawn material currently considered mill waste is suitable for the production of particle board. Exploratory tests at the Forest Products Laboratory have shown that ponderosa pine is well suited to particle-board manufacture. Specific products that should warrant consideration include flake-type furniture-core particle board, a furniture core or underlayment board made from standard planer shavings, and a newly developed thick board made from pulp-type chips in combination with standard flakes.

Appropriate raw material was obtained to evaluate the feasibility of producing these particle-board products from low-grade ponderosa pine. Raw materials included one 12-foot grade 6 saw log, 500 pounds of debarked sawmill slabs, and 300 pounds of planer shavings (appendix A). The planer shavings were taken from the lower head of a 21-inch, Model 484M Woods planer.[8]

Two general types of particle board were manufactured. The first of these was conventional flat-press furniture-core particle board in six variations. The second type was the thick, three-layer chip and flake board designed for partitioning, with possible modification for decking use.

Flake and shaving board production

Furniture-core particle boards made of conventional flakes, of planer shavings, and of a combination of the two were included in the tests. Six types or variations of particle board were selected for manufacture, including:

1. Shavings board: This board was made to Forest Products Laboratory standard specifications,[9] with planer shavings from a typical commercial high-speed planer.

2. Flake-shaving board: This board was made to standard specifications from flakes nominally 1 inch long, 0.015 inch thick, and random width, and planer shavings mixed at a weight ratio of one to one.

3. Three-layer flake board: This board contained a core made from conventional flakes nominally 1 inch long, 0.025 inch thick, and random width. Each face layer, comprising one-eighth of the total weight of wood material, was made of flakes 1 inch long, 0.005 to 0.010 inch thick, and random width.

4. Three-layer flake-shaving board: This board contained a core made of conventional flakes 1 inch long, 0.025 to 0.030 inch thick, and random width. Each face layer, comprising one-eighth of the total weight of wood material, was made of fines produced by hammer-milling planer shavings.

[8]*Mention of trade names and commercial enterprises or products is solely for necessary information. No endorsement by the U. S. Department of Agriculture is implied.*

[9]*Specifications designated as standard by the Forest Products Laboratory are described on page 16.*

5. Forest Products Laboratory standard particle board: This board was made entirely from conventional ponderosa pine flakes nominally 1 inch long, 0.015 inch thick, and random width.

6-7. Two-layer flake board: This board was made from conventional ponderosa pine flakes 1 inch long, 0.015 inch thick, and random width, with a top layer of fine material. The fine material, comprising one-eighth of the total weight of wood material, was produced by hammer-milling flakes. Two series of these boards were made, one with phenolic binder, the other with urea binder.

The conventional flakes used in manufacturing the particle boards were prepared from the sawmill slabs provided, and from other scrap material. The material was cut into blocks 3 inches long in the grain direction to facilitate flaking on the laboratory flaker. The blocks were vacuum soaked in an autoclave to raise the moisture content to a point approximating green wood. When removed from the autoclave, the material had an average moisture content of 107 percent.

Sufficient flakes of the specified dimensions for each type of particle board were cut with a small laboratory flaker. The material was fed into the flaker with direction of grain parallel to the plane of rotation of the disc-type cutter head. The knives on the cutter head were adjusted to control thickness of flake, and spur cutters similarly controlled length of flake in the grain direction. All wet material flaked without difficulty. Flaking attempted with some air-dry blocks at 12 percent moisture content was unsuccessful. The dry material flaked irregularly and produced badly curled flakes. Some difficulty was also experienced in cutting 0.005-inch-thick flakes from either wet or dry blocks. Again wet blocks exhibited superior flaking properties.

The flakes were allowed to air dry to approximately 15 percent moisture content, then were hammer-milled just sufficiently to break them into random widths. Smaller particles were removed by screening the hammer-milled flakes through a 16-mesh screen. A quantity of flakes and a similar quantity of planer shavings were hammer-milled in a 1/16-inch hammer-mill screen to produce fine material for the faces of multi-ply boards. All material was dried to approximately 6 percent moisture content before use.

A sample of each group of flakes was measured to determine the range of flake thickness. Table 8 indicates the total thickness range encountered, and the thickness range encompassing 90 percent or more of the flakes, for each nominal flake thickness.

Table 8.--Range of flake thickness in a sample of ponderosa pine flakes, measured at 6 percent moisture content

Nominal thickness (Inches)	Thickness range		
	Minimum	Maximum	Including 90% of flakes
	- - - - Inches - - - -		
0.005-0.010	0.004	0.012	0.005-0.009
.015	.010	.019	.012- .017
.025- .030	.020	.038	.025- .034

Three boards of each of the six types of conventional particle board under consideration were manufactured. Liquid urea-formaldehyde adhesive was applied to the particles by spraying. The boards were felted by hand, following the specifications previously discussed for each type of board. All boards were formed and pressed to the following Forest Products Laboratory standard specifications:

1. Gross size: 1/2 inch by 24 inches by 28 inches.
2. Density: 35 pounds per cubic foot.
3. Moisture content of particles before spraying: 6 percent.
4. Resin: Liquid urea formaldehyde, uncatalyzed. In addition, three boards of the two-layer flake board type were made with a phenolic-resin adhesive.
5. Resin content: 8 percent.
6. Moisture content of particles before pressing: 12 percent.
7. Temperature of press: 325° F.
8. Pressure: Press to 1/2-inch stops in 3 to 4 minutes.
9. Time in press: 15 minutes.

The boards were cut into test specimens to be subjected to standard strength and dimensional stability tests. The strength tests included internal bond and static bending strength determinations. Dimensional stability tests included subjecting specimens of each type of board to the following conditions:

1. Vacuum-pressure soak.
2. Soak.
3. Ovendrying.
4. 80° F., 30 percent relative humidity.
5. 80° F., 65 percent relative humidity.
6. 80° F., 80 percent relative humidity.
7. 80° F., 90 percent relative humidity.

Three-layer-thick particle board production

The second type of particle board considered was a board 1-3/4 inches thick with a core of conventional 5/8-inch pulp chips and face layers of conventional 0.015-inch by 1-inch, random width, flakes. This type of board, although in the early experimental stage at present, offers considerable promise as a partitioning and, with modification, decking material. Coarse chips for such a board can be produced from extremely low-grade, rough material, including low-grade logs and debarked slabs.

The grade 6 ponderosa pine saw log provided as test material was canted and chipped into conventional 5/8-inch pulp chips to provide core material. Face material consisted of the standard 1-inch by 0.015-inch flakes of random width previously described. The flakes used in each face comprised one-eighth of the total weight of wood material in the board.

Six test boards 24 by 28 inches were manufactured, three with a phenolic resin binder and three with a urea-formaldehyde binder. The liquid adhesive was applied to the particles by spraying. The boards were felted by hand and all boards were formed and pressed to the following specifications:

1. Gross size: 1-3/4 inches by 24 inches by 28 inches.
2. Density: 22 pounds per cubic foot.
3. Moisture content of particles before spraying: 6 percent.
4. Resin: Liquid urea formaldehyde, uncatalyzed. Phenolic resin.
5. Resin content: Core, 4 percent.
   Faces, 8 percent.
6. Moisture content of particles before pressing: 12 percent.
7. Temperature of press: 325° F.
8. Pressure: 150 pounds per square inch maintained until the desired board thickness of 1-3/4 inches was attained, then adjusted to maintain thickness. Thickness is attained without press stops by using a dial indicator attached to a press platen.
9. Time in press: 55 minutes.

The boards were cut into test specimens to be subjected to the same strength and dimensional stability tests previously outlined for conventional boards.

In addition to the six test boards produced, sufficient material was on hand to manufacture seven boards 2 feet by 8 feet according to the same specifications used for the urea-bonded test boards (figs. 11, 12). The large boards were trimmed, the faces were sanded lightly, and a groove 1/2 inch square was routed down the center line of the edges of the boards. The groove provided for splining the boards together in a partition structure with strip molding machined in the form of a cross (fig. 13).

The press cycle time of 55 minutes used in the manufacture of this product need not necessarily be a deterrent to commercial production. Representatives of electronic equipment firms state that this type of product can be manufactured with extremely short cycle time through the use of radio-frequency heating. The most efficient pressing operation would probably combine steam-heated platens and radio-frequency heating. Conventional steam-heated presses can be converted to this type of unit through the addition of electronic insulation and radio-frequency energized platens. It has been estimated that a 15-kilowatt radio-frequency unit would be sufficient to reduce press cycle time to approximately 2 minutes for particle board 1-3/4 inches thick. The product would also lend itself well to manufacture in a Chapman-type progressive press.

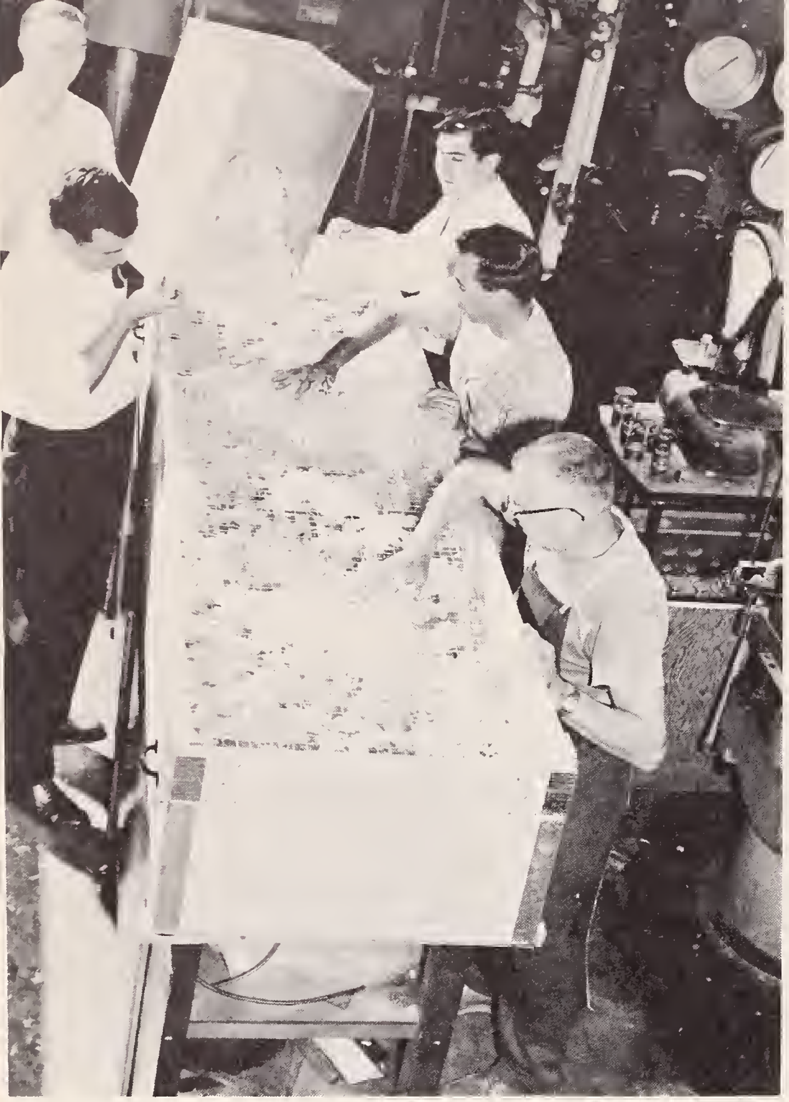


Figure 11.--The 1-3/4-inch, 2-foot by 8-foot particle boards were felted by hand through a screen to achieve particle distribution.

Particle board strength tests

The ponderosa pine particle boards were tested for strength in static bending and internal bond. Five specimens for each test were taken from each board. The average strength values observed in the tests are given in table 9.

For comparative purposes, Commercial Standard CS 236-61[10] sets the following minimum allowable limits for mat-formed particle board:

Property	Individual minimum	Average of 10, minimum
	(lbs./sq. in.)	
Modulus of rupture	1,450	1,600
Modulus of elasticity	200,000	250,000
Internal bond	50	60

[10]*U. S. Department of Commerce. U. S. commercial standard CS 236-61 for mat-formed particle board (interior use). 9 pp., illus. June 1961.*

Figure 12.--The mats for these hand-felted boards were then hot-pressed at 325°F. to the desired thickness.

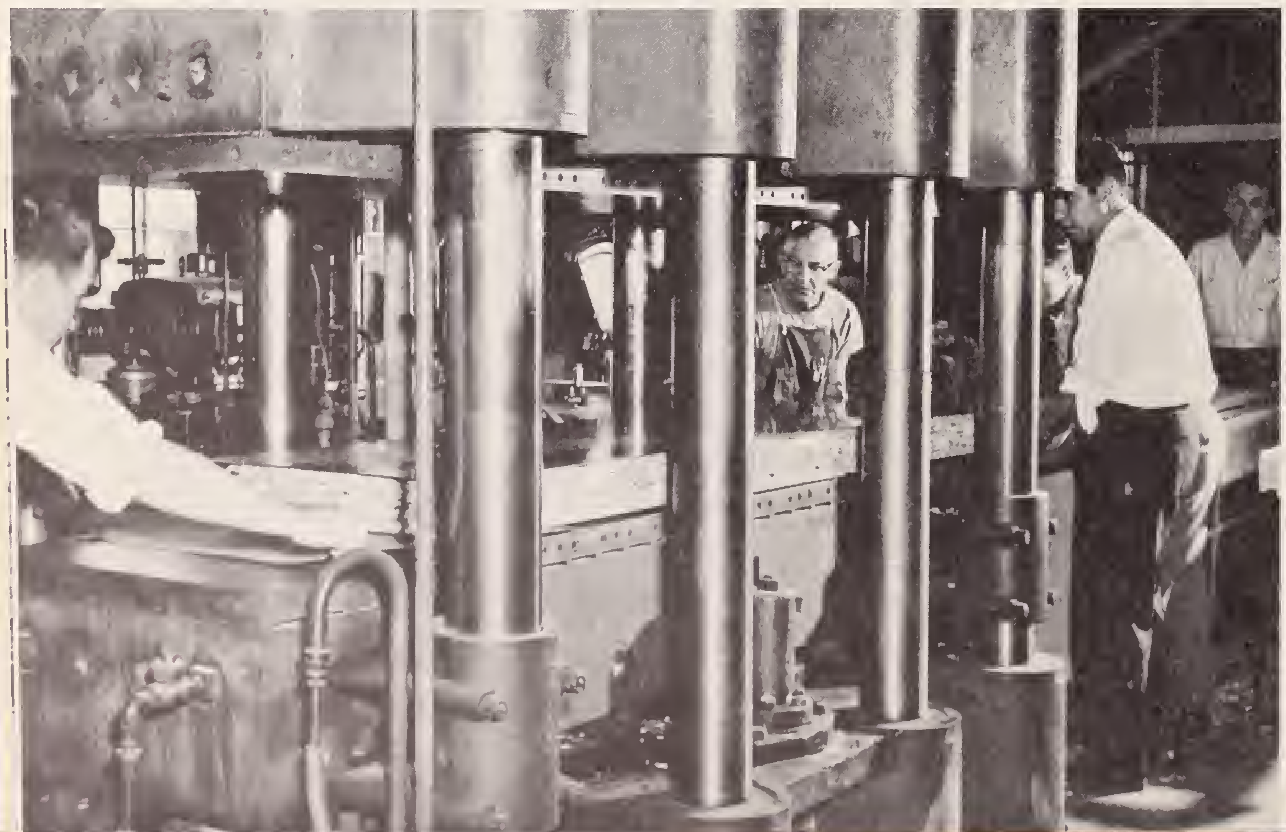


Figure 13.--A completed particle board partition, with connecting cross-shaped splines (insert) painted dull black.

Table 9.--Summary of strength characteristics of ponderosa pine particle boards[1]

Board number and description	Moisture content	Modulus of--		Tension perpendicular (internal bond)
		rupture	elasticity	
	Percent	Lbs./sq.in.	1,000 lbs./sq.in.	Lbs./sq.in.
Standard 1/2-inch ponderosa pine boards:				
1. Planer shavings board	9.2	950	120	115
2. Shaving and flake board	8.8	2,220	280	115
3. Three-layer flake board	8.6	2,660	400	25
4. Three-layer flake and shaving board	8.7	1,960	250	135
5. FPL standard particle board	8.4	3,720	460	110
6. Two-layer flake board	8.9	3,440	465	90
7. Two-layer flake board, with phenolic binder	8.6	3,200	400	120
Comparative 1/2-inch Douglas-fir boards:				
8. FPL standard Douglas-fir board (40 lbs./cu.ft.)	8.6	4,020	570	150
Thick 1 3/4-inch chip-core boards:				
9. Three-layer chip and flake board (22 lbs./cu.ft.)	9.0	770	140	23
10. Three-layer chip and flake board, with phenolic binder (22 lbs./cu.ft.)	8.8	830	150	22

[1] Detailed description of individual boards in text. All boards, unless otherwise noted, have density of 35 lbs./cu.ft., and were manufactured with 8 percent urea binder. Data for boards 1 through 4 based on 5 test specimens taken from a single board of each type; boards 5 through 10 based on 15 test specimens, 5 taken from each of 3 boards of each type.

Comparing these minimum limits to the data shown in table 9 provides a means of judging the performance of the boards. Except for boards 1 and 3, all the 1/2-inch boards (numbers 2,4,5,6,7) met or exceeded the minimum allowable limits. Boards made under controlled laboratory conditions, however, are generally stronger in static bending and internal bond than similar boards made on a production basis. Therefore, boards 2 and 4 should also be considered marginal or unsatisfactory with respect to modulus of elasticity.

The low internal bond of board 3 is probably the result of a pressing variable such as pressure, since all failures occurred in the lower 1/16 inch of the press downside of each specimen.

The low modulus of elasticity obtained in boards 1, 2, and 4 appears to be directly related to the use of planer shavings in these boards. Within a species, static bending strength tends to increase and internal bond tends to decrease as particle shape becomes more flakelike. A flake board is in effect made up of layers that have good resistance to static bending loads. This layered effect is not so pronounced in boards containing planer shavings. Boards made with planer shavings, then, could be expected to possess good internal bond strength and only fair bending strength. Both of these properties will be further reduced if the planer shavings are excessively curled, as were the shavings used in this study. It is difficult to obtain a resin coat on the inside of the curl, consequently the adjacent faces of a compressed shaving may contain little or no resin and will weaken the board.

Board 8, representing the average of six Douglas-fir standard particle boards, was included for comparison. Except for density, they were manufactured in the same manner as ponderosa pine standard particle board 5. With density of 40 pounds per cubic foot for Douglas-fir, better strength properties are expected. Allowing for the density difference, the ponderosa pine flake boards 5, 6, and 7 compare favorably in all respects. It appears that a board comparable to Douglas-fir board can be made from ponderosa pine.

Boards 9 and 10 in table 9 are the 1-3/4-inch thick, chip-core construction. Their density of 22 pounds per cubic foot is less than that of solid ponderosa pine wood. Because of the special type of construction, they would not be expected to meet the minimum strength specifications required of standard particle board. While the strength values of these boards were not high, they seemed sufficient for the suggested uses of wall partitions and roof decking. In comparison, a commercial fiberboard roof decking, with a density of about 19 pounds per cubic foot, has a stiffness and strength in bending of about one-half the values obtained for the experimental chip-core board.

Particle board dimensional movement tests

The acceptability of particle boards for many uses, such as underlayment, core stock, and paneling is often based on properties other than strength and stiffness. "Show-through" or "telegraphing" is important in boards to be used as cores in desk tops and furniture; edge texture and screw-holding capacity are of importance in furniture applications. Of vital importance in almost all applications of particle board are the linear and thickness dimensional movements associated with changes in moisture content.

To evaluate dimensional movement properties of the test boards, 24-inch-long strips were cut from the samples. The thickness and length of these strips were accurately measured before and after exposure to ovendrying; 30 percent, 65 percent, 80 percent, and 90 percent relative humidity at 80° F.; and submersion under water. One strip was exposed to each condition after preconditioning at 30 percent relative humidity. The results of the evaluation are presented in table 10.

With the exception of board number 1, the linear movements shown in table 10 are quite small and compare favorably with standard Douglas-fir flake board 8. The thickness movements of the 1/2-inch ponderosa pine boards also compare favorably with the Douglas-fir board. Only the board composed entirely of planer shavings exhibited excessive dimensional movement. By comparison,

Table 10. --Dimensional movement of ponderosa pine particle boards[1] associated with changes in moisture content

Board number and description	Change in thickness: From ovendry to soaked condition	Change in thickness: Thickness movement index[2]	Change in length: From ovendry to soaked condition	Change in length: Linear movement index[2]	Change in length: From 50 to 90% relative humidity[3]
	- - - - - - - - - -	- - - - -	Percent	- - - - -	- - - - - - - - - -
Standard 1/2-inch ponderosa pine boards:					
1. Planer shavings board	34	14.6	1.72	0.81	0.54
2. Shaving and flake board	37	15.0	.46	.31	.19
3. Three-layer flake board	40	16.5	.24	.21	.04
4. Three-layer flake and shaving board	32	12.8	.32	.24	.08
5. FPL standard particle board	35	14.0	.29	.23	.06
6. Two-layer flake board	32	12.8	.29	.23	.08
7. Two-layer flake board, with phenolic binder	25	11.6	.21	.21	.06
Comparative 1/2-inch Douglas-fir boards:					
8. FPL standard Douglas-fir board (40 lbs./cu.ft.)	34	14.1	.30	.23	.05
Thick 1 3/4-inch chip-core boards:					
9. Three-layer chip and flake board (22 lbs./cu.ft.)	11	4.3	.40	.27	.17
10. Three-layer chip and flake board, with phenolic binder (22 lbs./cu.ft.)	8	3.6	.37	.28	.16

[1] All boards, unless otherwise noted, have density of 35 lbs./cu.ft., and were manufactured with 8 percent urea binder.
[2] Based upon difference between ovendry dimension and average of dimensions at 30, 65, 80, and 90 percent relative humidity, and soaked.
[3] Maximum movement allowed under Commercial Standard specifications is 0.50 percent.

a currently available commercial flake-type particle board, designed primarily for furniture core use, has a linear movement index of about 0.05 and a thickness movement index of about 12 percent. Another commercial particle board, designed primarily for use as underlayment, has a linear movement index of 0.63 and a thickness movement index of 11 percent.

No tests were made on the sample boards to evaluate screw-holding capacity or show-through. The edge condition of the test boards, as judged by visual comparison, appears to be acceptable and comparable to commercially available boards.

Results of the dimensional movement tests indicate that flake-type particle boards properly made from ponderosa pine waste could be expected to compete with good commercial particle boards, with respect to linear dimensional movement. Thickness movement of the experimental boards is not significantly different from that of commercial boards.

The 1-3/4-inch thick chip-core particle boards 9 and 10 (table 10) exhibited extremely low dimensional movement in both thickness and length. Both thickness movement and linear movement are well below those of high-quality commercial particle boards of conventional construction.

Specimens of the 1-3/4-inch thick phenolic-bonded chip-core particle board were also subjected to six cycles of accelerated aging. No strength tests were made, but the material

was observed between cycles and inspected closely after completion of the cycles. The thick material appeared to be no more affected by aging than conventional types of particle board, and perhaps less than some wood products that give satisfactory service under exterior use. The board appears to have superior qualifications for suggested uses.

The strength and dimensional movement tests performed on the conventional flake-type particle boards and the thick chip-core particle board indicate that ponderosa pine is well suited to this use. There should be no difficulty in designing particle board of ponderosa pine that could technically equal or surpass many of the currently available boards in the furniture core market and underlayment market. There appears to be a similar potential for the experimental thick board, in the partition and roof decking market.

Laminated Beams

Smaller vertically laminated beams suitable for roof beams or floor joints in conventional small building construction offer promise for effectively utilizing lower grade ponderosa pine lumber. Laminating low-grade material into conventional laminated structural timbers would not be practical nor economical. Producing vertically laminated beams made from full-length boards, however, seems to have some practical possibilities. Laminating provides an opportunity for obtaining either a random or selected distribution of strength-reducing characteristics throughout the beam. With a suitable orientation of defects, low-grade lumber can be used to produce beams of adequate strength for specified construction uses. Such beams can provide a necessary part of a coordinated component building system for use in conjunction with flooring or decking products, especially where deflection governs in design. Further, locally produced laminated members can reduce checking problems encountered when laminated members manufactured in humid regions are used in the Southwest.

Beam construction

The feasibility of vertically laminating small beams from full-length standard sizes of 4/4 low-grade lumber was investigated by making five-ply laminated joist beams from 1- by 10-inch lumber. The test lumber, all 16 feet in length, included approximately equal amounts of grades 3, 4, and 5 common (appendix A). It had previously been surfaced on two sides to a standard thickness of 25/32 inch. Some of the pieces had areas of planer skip on one or both faces.

Boards were randomly selected for 10 beams; grade 3 common boards were assigned to the outer beam faces for appearance. Inner laminations were of grades 4 and 5 common; laminations two and four were of a like grade.

The laminations of beams 1 through 5 were left exactly as they occurred in random layup. No attempt was made to improve defect orientation.

In beams 6 through 10, the randomly selected boards were reoriented or interchanged so that strength-reducing characteristics would be distributed in a position judged to have the least effect on bending strength and stiffness. Grade 3 common boards were retained on the outer faces. The best edge of each board was placed downward, toward the tension side of the beam. It was intended that the results obtained in testing this group, when compared to the group made up of beams 1 through 5, should provide an indication of the value of such reorientation.

After selection of the material for the first 10 beams, 7 randomly selected boards remained. The five poorest boards remaining were assigned to beam 11, and were oriented to concentrate the knots along the tension side of the beam. The outer or face laminations were grade 5 common, and the inner three laminations were grade 4 common. The beam was laid up in this manner to gain some idea of the worst condition that might occur in purely random layup.

The laminations of each beam were laid out in order, graduated at 4-foot intervals, numbered with beam and lamination number,

and marked to indicate designated tension edge (fig. 14). Both faces of each lamination were photographed, as a record of defect location within the beam. The beams were dead piled and covered until glued.

The stresses applied on the glue lines of vertically laminated beams by external loads are normally appreciably less than on glue lines of horizontally laminated beams. Therefore, exacting glue-laminating procedures are of lesser importance. The boards had been surfaced at the mill prior to shipment to the Laboratory. To simulate economical production procedures, the boards were glued into beams without further surfacing. The beams would presumably be handled as stock lumber yard items, and would perhaps be exposed to the weather, both in the yard and in subsequent use. Consequently, a room-temperature-setting phenol-resorcinol adhesive suitable for exterior exposure was specified.

Further economy in laminating was simulated by applying glue to both surfaces of laminations 2 and 4 only, as is done in making conventional plywood (fig. 15). These two laminations were double-spread by passing them through a double-roll 18-inch glue spreader. The remaining laminations (1, 3, and 5) were not spread at all. Many of the boards were slightly cupped and warped, which caused the glue-spread to vary from place to place on the board. In beams 3 through 11, the spread laminations were passed through the spreader twice to obtain more uniform ad-

Figure 14.--These lower grade boards made up the laminations of a typical beam. The composite photo shows both front and back of all five laminations.

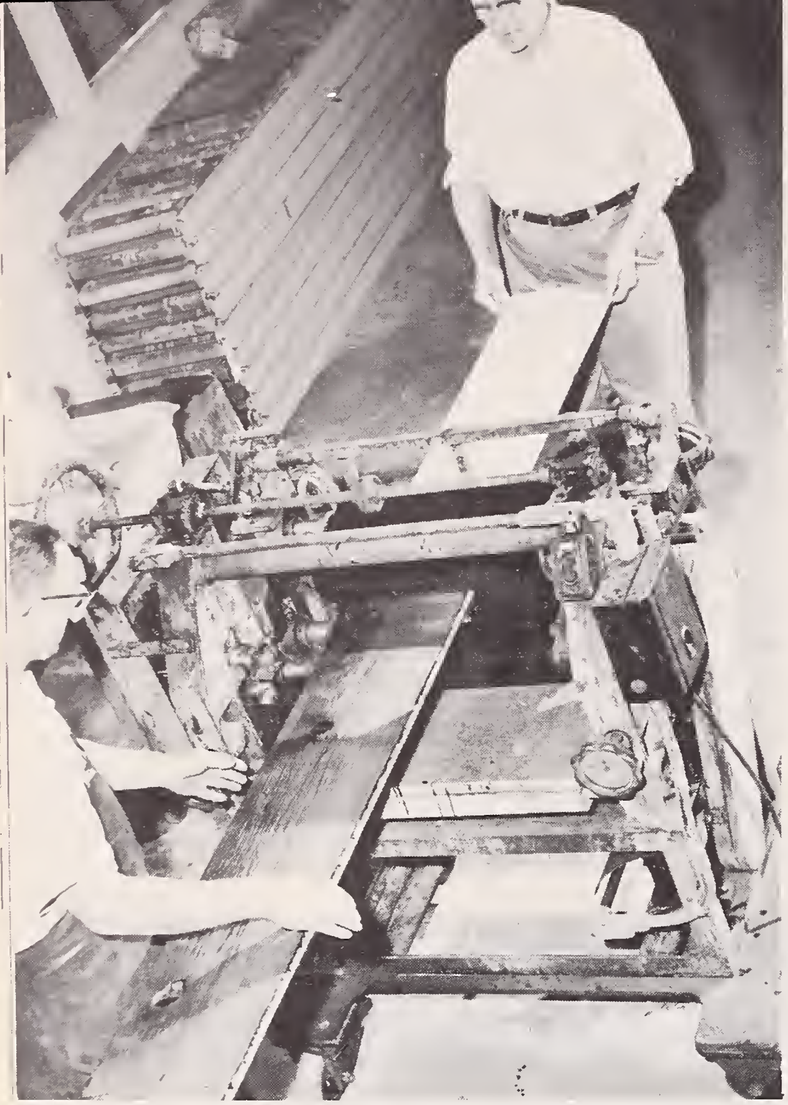


Figure 15.--Second and fourth laminations of the beams were double-spread with phenol-resorcinol adhesive, in a double-roll spreader equipped with doctor rolls.

hesive coverage. The average spread for all beams was estimated at 40-45 pounds per M square feet of glue-joint area.

Areas of complete planer skip did not spread well at all. Areas of partial skip, from which the roughest surface had been removed, spread without difficulty.

The beams were laid up in pairs in a hand clamping jig, between 2- by 12-inch caul boards. Side clamps were used to align the laminations and remove bow while pressure was applied (fig. 16). Side clamping was hampered by variations in the width of the surface-two-sides (S2S) laminations. Laminations of uniform width would prove a definite advantage.

Pressure clamps were located on approximate 8-inch centers along the length of the 16-foot beams. The clamps were uniformly loaded with a torque wrench to apply approximately 150 pounds per square inch glue-line pressure.

Total assembly time for the beams averaged approximately 25 minutes, of which less than 5 minutes was open assembly time. The beams remained in the clamps at room temperature for a minimum of 18 hours. After the clamps were removed, the beams were allowed to cure for 3 weeks in a controlled atmosphere at 73° F. and 50 percent relative humidity. The beams were then dressed to a uniform depth of 9-1/2 inches. Each beam was slightly over 3-7/8 inches wide, 9-1/2 inches deep, and 16 feet long.

Beam tests and evaluation

All beams were tested in static bending to determine strength and stiffness characteristics. The beams were simply supported over a span of 15 feet and subjected to two-point loading with load points 5 feet apart (fig. 17). The results of these tests for the 11 beams are shown in table 11.

For comparative purposes, average values for clear straight-grained ponderosa pine at

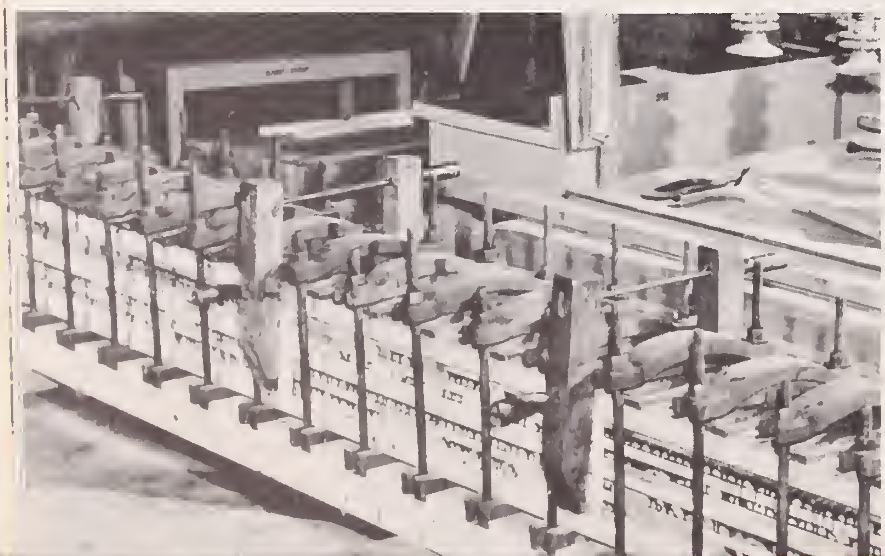


Figure 16.--Immediately after a beam was laid up, side clamps were applied to align the edges of laminations and remove bow. Pressure clamps were then applied to the beams at 8-inch intervals.

Figure 17.--A test beam positioned in a screw-type testing machine.

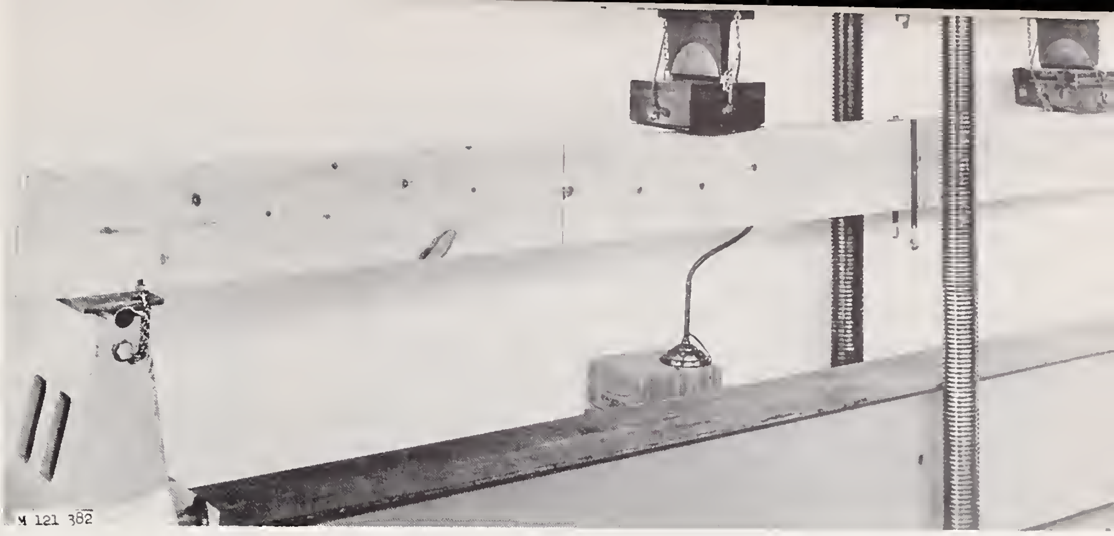


Table 11.--Physical characteristics of vertically laminated 16-foot beams made of low-grade ponderosa pine

Beam No.	Width	Depth	Weight	Moisture content[1]	Specific gravity[2]	Modulus of elasticity	Stress at proportional limit	Modulus of rupture	Corrected modulus of rupture[3]
	Inches		Lbs.	Percent		1,000 lbs./sq.in.	- -	Lbs./sq.in.	- -
				GROUP 1 -- RANDOM SELECTION AND LAYUP					
1	3.93	9.51	126.5	9.9	0.44	1,160	2,280	3,570	3,100
2	3.91	9.51	135.5	13.1	.46	1,240	2,550	3,930	3,190
3	3.93	9.52	135.0	11.4	.47	1,080	2,020	3,140	2,470
4	3.93	9.54	131.0	10.2	.46	1,180	3,520	4,240	3,440
5	3.95	9.52	128.2	10.7	.44	1,100	3,270	3,950	3,420
Average				11.1	.46	1,150	2,730	3,770	3,120
				GROUP 2 -- RANDOM SELECTION WITH SPECIAL ORIENTATION IN LAYUP					
6	3.92	9.52	129.5	10.8	.45	1,110	3,290	5,740	4,810
7	3.91	9.51	124.5	11.4	.43	1,080	2,550	4,410	3,960
8	3.92	9.52	124.5	10.9	.44	1,210	3,800	5,440	4,720
9	3.93	9.51	132.2	11.1	.46	1,340	3,800	5,340	4,330
10	3.88	9.54	120.0	11.7	.42	1,200	3,060	4,540	4,220
Average				11.2	.44	1,190	3,300	5,090	4,410
				SPECIAL BEAM					
11	3.92	9.54	145.0	12.2	.50	1,030	3,030	4,170	2,980
Overall average				11.2	.45	1,160	3,020	4,410	3,690
Species average[4]				12.0	.40	1,260	6,300	9,200	9,200

[1] Based on sample sections 1 inch long and free of knots; expressed in terms of ovendry weight.
[2] Based on volume of beam at test and estimated ovendry weight of beam.
[3] Corrected to a specific gravity of 0.40.
[4] Taken from: Markwardt, L. J., and Wilson, T. R. C. Strength and related properties of woods grown in the United States. U. S. Dept. Agr. Tech. Bul. 479 (face p. 4). 1935.

12 percent moisture content are shown at the bottom of the table.

Beam 11 was laid up to obtain a heavy concentration of strength-reducing characteristics on the tensile side, thus approximating the worst condition that could occur in random layup. The beam was inadvertently tested with the best, however, rather than worst, edge on the tensile side. The modulus of elasticity was still the lowest of any of the beams tested, indicating that this property is affected by grade of laminations.

The data in table 11 indicate that the strength of beams made by vertically laminating boards of low quality can be increased significantly by selective orientation of the laminations. Dispersing strength-reducing characteristics and placing the poorer edges of the boards on the compression side of the beam result in a substantial increase in stress at proportional limit and modulus of rupture. The average modulus of rupture for the second group of beams is about 35 percent higher than that for the random layup group. Furthermore, the minimum modulus of rupture value in the second group is higher than the maximum value in the random layup group.

A selective orienting procedure in production would require that top and bottom of the beams be positively identified to prevent improper installation. If they were inadvertently placed upside down, their bending strength could be one-half or less of that expected with proper placement.

Failure of all beams during the bending tests started in the wood in an area adjacent to knots or cross grain, on the tension side of the beam. There was no evidence that weak glue bonds contributed to the initial failure. The gluing procedures used in constructing the test beams appear to provide a glue bond of adequate strength for the purpose intended.

The glue bond should also be sufficiently durable to withstand stresses due to environmental conditions to which the member will be exposed. To evaluate durability of the glue bond, a cross section was cut from each beam and subjected to delamination tests. The results of the delamination tests were generally satisfactory; some delamination was observed in resinous areas of the beams, however, and appeared to be directly associated with the presence of resin.

The results of the beam-strength tests and glue-bond tests lead to the conclusion that the gluing techniques used, and the glue spread of 40-45 pounds per M square feet, are adequate for the product. They are close to minimum for acceptable performance, however. The delamination tests further indicate that boards with relatively large areas of heavy resin should be culled from laminating stock.

Average specific gravity of the beams was 0.45 as compared with an average value of 0.40 reported for the species. A second evaluation of specific gravity, from only clear wood specimens, confirmed the 0.45 value. If the average specific gravity of the beams had been 0.40 and all other factors were the same, somewhat lower values of strength and stiffness would be expected. Values of modulus of rupture corrected to a specific gravity of 0.40 were calculated for each beam, and are shown in the last column of table 11.

Vertically laminated beams of the type evaluated have been suggested for use as floor joists spaced on 4-foot centers. Deflection limitations rather than strength frequently govern in design of such structures. For floor systems, the deflection is often limited to 1/360 of the span. If such a deflection limit, a total floor load of 40 pounds per square foot, and 4-foot spacing are assumed, the strength and stiffness of the beams appears to be adequate for spans up to about 13 feet.

The results of the evaluation are too limited to provide a basis for design recommendations. However, beams of the size, type, and construction evaluated show definite promise of being practical for use in floor and roof systems in housing and other building construction. The strength of such beams can be increased significantly by the selective orientation of defects during production.

Overlaid Siding

Overlaying lumber with fiber sheet products offers utilization possibilities for low-

grade ponderosa pine. Of particular interest in this study was the possibility of using selective cuttings from mill-run grade 3, 4, and 5 common lumber to produce overlaid products of exceptional quality and surface appearance. Overlaid products with a higher market value than sheathing were emphasized, since they can better withstand the costs of selective cutting and processing.

For the utilization of low-grade 4/4 and 5/4 lumber, two Laboratory-developed siding products were considered: a combination siding-sheathing product from 4/4 lumber, and a resawn beveled siding product from 5/4 lumber. Both were produced from the 4/4 and 6/4 rough test lumber supplied.

A rather wide range of overlay materials for wood has been developed on an experimental basis in recent years. Selection of the correct overlay material for the design and type of product and ultimate end use is extremely important. The two overlaid siding products manufactured from ponderosa pine presented somewhat different requirements for overlay material. The combination siding-sheathing product, because of the exposure conditions encountered in its use, required overlaying on both front and back. An overlay that restricted dimensional movement was considered desirable. In addition, the siding was end and edge matched with tongue and groove, and was beveled to create a drip edge and shadow line. The overlay material used in such an application should, therefore, machine well and cut cleanly without fraying. The overlay material specified for this siding was made at the Laboratory from kraft pulp blended with 15 to 18 percent of water-dispersible phenolic resin at the beater. The included resin adds tensile strength and durability to the overlay, and provides desirable machining characteristics. Prior to use, the overlay material was fully cured in a steam-heated press at 300° F.

The overlay described is considerably more stable dimensionally in the machine direction than in the cross-machine direction. Consequently, for maximum restraint of dimensional movement of the siding, the machine direction of the overlay should be at right angles to the direction of grain in the lumber. This requires overlay material as wide as the length of the siding. If overlay material of this type is locally manufactured, but in inadequate widths, dimensional stability in the cross-machine direction can be increased through the use of expander rolls on the paper machine. The curved expander rolls exert a sidewise pull on the fiber web, and restrain it from shrinking as it dries. The resulting overlay has improved dimensional stability in the cross-machine direction, and performs well when applied lengthwise to the lumber.

The second siding product manufactured, a resawn beveled siding, could be overlaid on the weather face only, because of the method of manufacture. In addition, a single-face overlay was considered adequate for the end use contemplated. The product, therefore, required an overlay material that would not restrain dimensional movement of the wood, and would produce an essentially stress-free construction when applied to only one side. For this product, 0.005-inch vulcanized fiber overlay was specified. The vulcanized fiber used as an overlay is essentially unsized, unloaded paper that has been treated with zinc chloride solution. This material has dimensional movement characteristics across the machine direction quite similar to those of wood in the tangential direction; therefore it can be used effectively in a single-face application. Specific orientation of the machine direction of the fiber sheet with grain direction of the siding is necessary. Like vulcanized fiber, parchmentized paper also performs satisfactorily as a single-face overlay.

Combination siding-sheathing production

The 4/4 rough test lumber for the combination siding-sheathing was random-width material 12 feet long. Moisture content of the stock ranged from 8 to 10 percent, a satisfactory compromise for ultimate use either in the Southwest or at Madison, where moisture content of wood in use may range from 8 to 12 percent. For use specifically in the Southwest, lumber stock probably should not exceed 8 to 9 percent moisture content when processed.

The lumber was surfaced on the best face, at a 15/16-inch planer bed setting, to obtain a working face and a relatively uniform thickness. In commercial production, it would be desirable to joint this working face rather than plane it, to circumvent cupping in wider stock.

All lumber was edge jointed and ripped random width for recovery of material suitable for overlaying. The material was ripped to obtain the widest possible pieces; the recovery included pieces from 1-1/2 to 10 inches wide. Lumber that could be used full width was trimmed and jointed to obtain straight, parallel edges.

Material judged suitable for overlay included knots of any size, so long as sound and not deeply chipped. Pitch seams, pitch pocket, stain, borer holes up to 1/16 inch across, open defects up to 1/32 inch wide, and open defects requiring plugs up to 2 inches in diameter were allowed on the face side. More open defect, including chipped knots, borer galleries up to 1/4 inch by 1 inch, slight wane edge, and machine gouge, was allowed on the back side.

End gluing was not attempted with the 4/4 material; consequently, cross cutting for added recovery was not considered. It is believed, however, that cross cutting and end gluing would not have appreciably increased the recovery.

Recovery from each grade of 4/4 test lumber is shown in table 12.

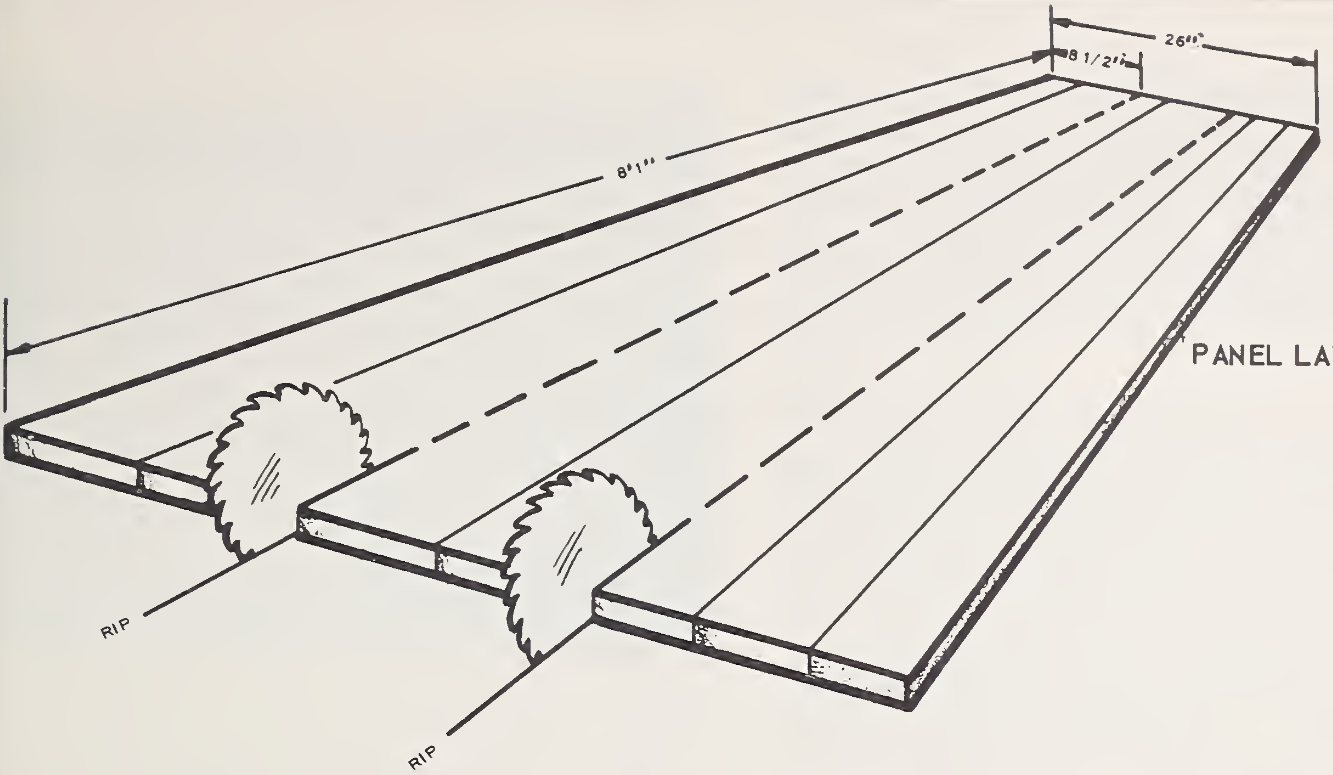
The ripped material was laid up in panel widths equal to three siding widths (fig. 18), and edge glued with a phenol-resorcinol resin glue. The working face of each panel was used as a reference surface to obtain flush alignment of the pieces. The panels were clamped in hand clamps for a period of 18-24 hours, at a room temperature of approximately 70° F. (fig. 19).

Table 12. --Recovery of overlaid combination siding-sheathing from 4/4 common lumber

Lumber grade	Initial volume	Rip loss		Panel volume	Manufacture loss[1]		Rough siding	Finished siding[2] coverage
	Bd.ft.	Bd.ft.	Pct.	Bd.ft.	Bd.ft.	Pct.	Bd.ft.	Sq.ft.
3	266	30	11.3	236	13	4.9	223	208
4	268	50	18.7	218	21	7.8	197	183
5	262	98	37.4	164	21	8.0	143	132
Total	796	178	22.4	618	55	6.9	563	523

[1] Attributable to kerf losses, panel trim loss, open glue joint, overlooked defects, etc.
[2] Based on 8-inch by 8-foot face coverage per piece.

Figure 19.--Edge-glued panels of 4/4 stock were hand clamped for 18 to 24 hours.



PANEL LAYUP DETAIL

CONSTRUCTION SPECIFICATIONS

(1) PANEL OF EDGE-GLUED RANDOM-WIDTH STOCK:

STOCK TO HAVE ONE SOUND FACE, LIMITED

OPEN DEFECT ON REVERSE.

(2) ROUGH PANEL SIZE 26 INCHES BY 8 FEET 1 INCH.

(3) FINISHED THICKNESS 11/16 INCH.

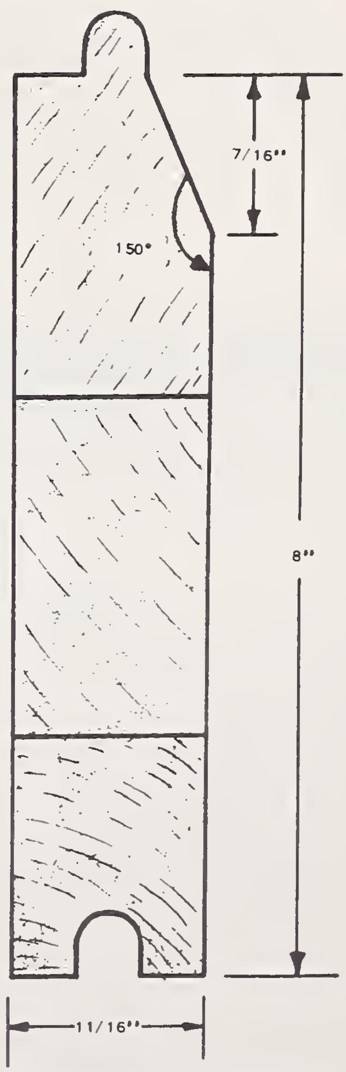
(4) OVERLAY BOTH SIDES WITH KRAFT SHEET,

PHENOL RESIN ADHESIVE, COLD PRESS.

(5) RIP TO 8½ INCH ROUGH WIDTHS.

(6) END AND EDGE MATCH AND BEVEL 30 DEGREES

TO FORM DRIP EDGE.



CROSS-SECTION SIDING DETAIL

Figure 18.--Manufacturing specifications developed for overlaid combination siding-sheathing.

The cured panels were surfaced to a finished thickness of 11/16 inch. A minimum cure time of 3 to 4 days is recommended before final surfacing of glued panels to prevent subsequent sunken glue joints. Panels that are appreciably warped or cupped may need to be rough ripped and face jointed in siding widths to relieve cupping.

A few open defects purposely left in the panels were drilled out and plugged with friction plugs. With the proper equipment for plugging, the process appears to be worthy of consideration for commercial application.

Since laboratory equipment limitations prohibited overlaying the material in full panel widths, all panels were first ripped into rough siding widths of 8-1/2 inches. Each piece of rough siding was numbered and photographed to provide a permanent record of defects and defect location (fig. 20). The photographs can be used to determine the location of specific defects under the overlay sheet.

Figure 20.--The rough-sized edge-glued siding stock was photographed to provide a record of defect location.

The completed rough-width siding stock was overlaid front and back with the resin-impregnated kraft overlay material previously described. The stock was double spread through a standard 18-inch roller spreader with an acid-catalyzed phenol resin adhesive at a spread of 30-35 pounds per M square feet of glue line. The overlay sheets were applied to each side, and the siding was placed in a cold press under 100 pounds per square inch pressure for 4 or more hours.

Figure 21.--Overlaid ponderosa pine siding-sheathing makes up part of the wall of a recently constructed Forest Products Laboratory building.

The overlaid stock was edge and end matched with standard tongue and groove to a face dimension of 8 inches wide by 8 feet long. A 7/16-inch bevel (approximately 30^{o}) was extended from the base of the tongue to the weather face (fig. 18) to provide some drip-edge and shadow-line effect (fig. 21).

In commercial production, many of the procedures used here could be automated or bypassed. The use of straight-line rip saws would eliminate the need for edge jointing layup stock. Material could go from rip saw directly to automated edge-glue equipment. Mechanical restraint applied to the faces of panels during edge gluing would help obtain flush alignment of the boards in panels. Edge-glued panels could be overlaid before being ripped into rough siding widths.

Resawn beveled siding production

The resawn beveled siding proposed for the study was designed to utilize 5/4 common lumber efficiently, rather than the 6/4 lumber provided. Consequently, the loss in volume experienced was considerably greater than would occur normally with 5/4 stock.

The rough 6/4 test lumber available was random-width material 12 feet long. A check of moisture content showed averages of 10 percent on the surface and 14 percent at the center of the stock. Both center and surface readings ranged up to 3 percent above and below the averages. Since the material was ultimately to be resawn, the 4 percent moisture gradient was considered excessive and likely to distort the resawn material. The overall range of moisture content was also greater than desirable. To reduce the variation in moisture content, reduce moisture gradient, and relieve any severe casehardening, the material was equalized and conditioned in a kiln according to the schedule shown in table 13.

After conditioning, sections were cut from each kiln sample for stress determination. The samples exhibited very slight casehardening, a desirable condition since up to 1/4 inch of material would be removed from each face of the stock during siding manufacture. Average moisture content of the stock after conditioning was 9.1 percent, with a spread of 0.7 percent among six samples.

The material was surfaced on two sides, reducing the thickness to 1-3/8 inches, to facilitate further processing. Had the material been 5/4 lumber, only one working face would have been surfaced initially. Pieces with any tendency to cup were face jointed prior to surfacing to thickness, since cupping could ultimately create resawing problems. In commercial production, it would be desirable to joint the working face of all material.

All material was edge jointed, then random-width ripped and cross cut for recovery of material suitable for overlaying. The recovery included pieces from 2 to 12 inches wide, and from 18 inches to 8 feet long.

The criteria employed in determining allowable defect in the panels were essentially the same as used in judging the 4/4 material.

Table 13.--Equalizing and conditioning schedule for 6/4 ponderosa pine[1]

		Dry bulb temperature	Kiln equivalent moisture content
WHEN:	Percent	Degrees F.	Percent
Desired final	10	--	--
Start equalizing when driest sample reaches	8	160	8
Stop equalizing when wettest sample reaches	10	--	--
Condition at	--	170	13

[1] Source: U. S. Forest Service, Forest Products Laboratory. Detection and relief of casehardening and final moisture content tests in kiln-dried lumber. FPL Tech. Note 213, 6 pp. Dec. 1958.

Table 14.--Recovery of overlaid resawn beveled siding from 6/4 common lumber

Lumber grade	Initial volume	Cutting loss		Rough panel volume	Manufacture loss[1]		Rough siding	Finished siding[2] coverage
	Bd.ft.	Bd.ft.	Pct.	Bd.ft.	Bd.ft.	Pct.	Bd.ft.	Sq.ft.
3	222	52	23.4	170	12	5.4	158	171
4	204	98	48.0	106	12	5.9	94	102
5	222	116	52.3	106	14	6.3	92	100
Total	648	266	41.0	382	38	5.9	344	373

[1] Attributable to kerf losses, panel trim loss, overlooked defects, etc.
[2] Based upon 1-1/2 inch overlap on installed siding, or 8-inch by 8-foot face coverage per piece.

Defects that would require plugging, however, were not allowed. Also, since both overlaid surfaces became weather faces in the finished product, requirements were the same for both faces.

Recovery from each grade of 6/4 test lumber is shown in table 14.

The board foot volume losses reflected in table 14 are comparatively large for two reasons:

1. The use of 6/4 material entailed starting with thicker test lumber than could efficiently be utilized by the siding pattern.

2. The material was similar to shop-grade lumber--large defects extending the full width of the piece--with short clear sections between. Much better recovery could be obtained from typical Common grade lumber. Much of the grade 3 test lumber approached a more typical Common grade 3, a fact reflected by the improved recovery from that grade.

The ripped and cross-cut material was laid up in panel widths equal to two siding widths (fig. 22). Full-length pieces were laid at each edge and at the rip line of the panel, with end-glued courses interspersed between. A double tongue-and-groove end joint was employed in end gluing the short stock. The joint facilitates end gluing, provides a smoother panel face by holding the pieces in alignment, and provides an added degree of strength in the completed panel.

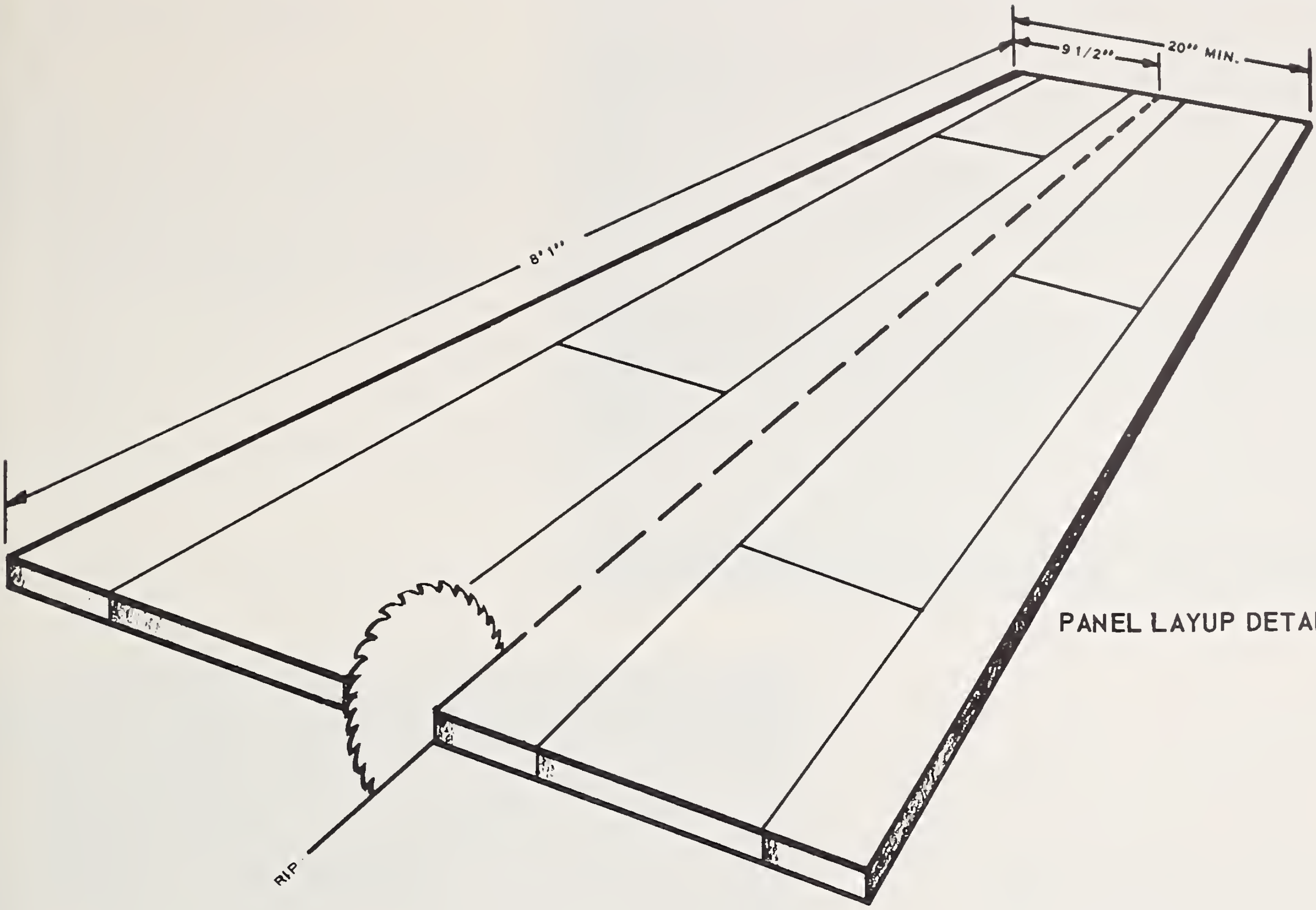
The panels were end and edge glued with a phenol resorcinol resin glue and clamped in hand clamps for a period of 18-24 hours, at a room temperature of approximately 70° F.

The cured panels were surfaced to a finished thickness of 1-1/16 inches. Equipment limitations prohibited overlaying the material in panel widths; consequently, all panels were ripped into rough-siding widths of 9-3/4 or 10 inches prior to overlaying. Each face of the double-thickness siding stock was numbered and photographed as a permanent record of defect location. Typical siding stock, before overlaying, is shown in figure 23.

The completed double-thickness siding stock was overlaid on both faces with the vulcanized fiber overlay material previously described. The stock was double spread through a standard roller spreader with an acid-catalyzed phenol resin adhesive at a spread of 30-35 pounds per M square feet. Overlay sheets were applied to each face, and the overlaid stock was cold pressed at 100 pounds per square inch for 4 or more hours.

The overlaid stock was end matched with a double tongue and groove (fig. 24), spaced to allow a single tongue and groove to remain on each piece of resawn siding. A 10-degree bevel was machined on each longitudinal edge to provide an undershot drip edge (fig. 22). The stock was resawn on a vertical band resaw, canted to produce the correct bevel in the finished product.

Again, much of the procedure employed in manufacturing this product could be simplified and automated in commercial production.



PANEL LAYUP DETAIL

CONSTRUCTION SPECIFICATIONS

(1) PANEL OF END- AND EDGE-GLUED RANDOM-SIZE STOCK: CONTINUOUS LENGTHS ALONG EDGES AND RIP LINE.

(2) STOCK TO HAVE TWO SOUND FACES.

(3) ROUGH PANEL SIZE 20 INCHES BY 8 FEET 1 INCH.

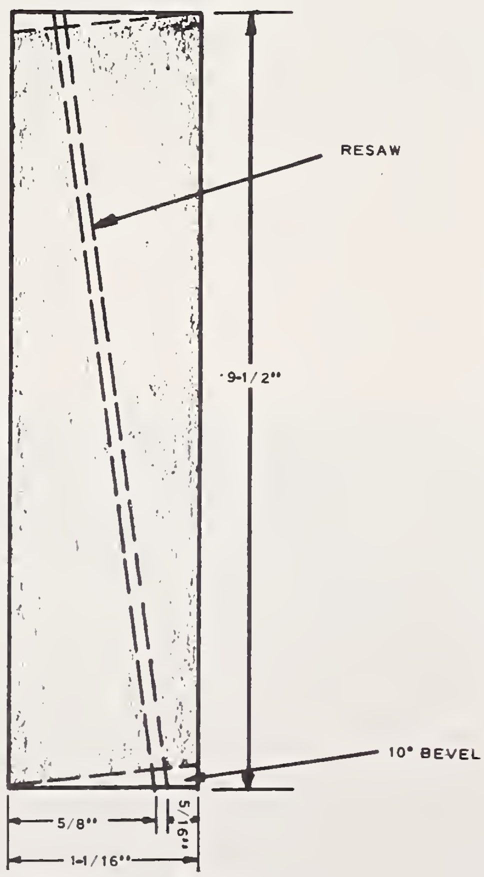
(4) FINISHED PANEL THICKNESS 1-1/16 INCHES.

(5) OVERLAY BOTH SIDES WITH VULCANIZED FIBER, PHENOL RESIN ADHESIVE, COLD PRESS.

(6) RIP TO 9¾-INCH ROUGH WIDTHS.

(7) BEVEL EDGES 10 DEGREES: END MATCH WITH DOUBLE TONGUE AND GROOVE.

(8) RESAW STOCK INTO BEVELED SIDING PATTERN.



CROSS-SECTION OF STOCK: RESAW AND BEVEL DETAIL

Figure 22.--Manufacturing specifications developed for overlaid resawn beveled siding.

Figure 23.--The double-thickness siding stock was photographed from both sides before it was overlaid to provide a record of defect location.

Figure 24.--The overlaid double-thickness siding stock is inspected before being resawn into standard beveled siding. Overlaid stock is end matched with a double tongue and groove spaced to allow a single tongue and groove to remain on each piece of resawn siding.

Figure 25.--Overlaid bevel siding is also in use on exterior of a new Forest Products Laboratory building.

Overlaid siding evaluation

Both overlaid siding products were manufactured without difficulty with very basic equipment. Much of the equipment used was improvised, or was designed for laboratory experimentation, and was much less suitable for the job than would be properly designed commercial equipment. Gluing and pressing procedures, and the overlays used, appeared to perform well and to provide a durable product (fig. 25). No major technological obstacles are foreseen in the commercial production of either type of overlaid siding.

The manufacture of overlaid products offers particular advantages to the sawmill industry because it can readily be integrated with sawmill operation. The necessary equipment requires a relatively modest capital investment, and is suitable for the manufacture of certain other cold-press laminated products as well. Automated selective cutting equipment and electronic end-and-edge glue equipment is becoming commonplace and available in units adaptable to relatively small production.

Experimental overlaid siding products have been exposed on test fences, and in service on buildings, at the Forest Products Laboratory for a number of years.[11] Overlays such as those used in the study have exhibited excellent resistance to deterioration, paint-holding ability far superior to wood, and high resistance to impact damage from hail stones or similar objects.

In addition to siding products, other overlaid products should also be considered. Overlaid panels in sizes of 2 feet by 8 feet or larger could perhaps find a substantial market for shelving, cabinet backing and interiors, and other construction uses where sheathing-grade materials are unsuitable. With a selective cutting process, a high-grade, clear, non-overlaid panel product may also be feasible.

[11] *Fleischer, H. O., and Heebink, Bruce G. Overlays for lumber--an old product in a new dress. U. S. Forest Serv. Forest Prod. Lab. Res. Note 035, 11 pp., illus. April 1964.*

Laminated Flooring

Two laminated flooring products appeared to offer considerable promise in utilizing low-grade ponderosa pine lumber and veneer. The two products specifically considered for demonstration and evaluation include a three-ply lumber-core combination subfloor and underlayment, and a two-ply lumber-base finished flooring. These products utilize lower grades of lumber in 5/8-inch and 25/32-inch thicknesses. In addition, lumber-core flooring would utilize ponderosa pine face and back veneers. Both products would be well suited for inclusion in a coordinated component construction system.

Lumber-core laminated flooring was conceived as a dual-purpose product, combining the functions of subfloor and underlayment in a single panel. It would thus serve the same functions as commercially available combination subfloor-underlayment products currently in wide use. Initial computations indicated that a panel using standard 25/32-inch lumber as a core, with face and back plies of pine veneer approximately 0.234 inch thick, would match the stiffness of commercial dual-purpose plywoods. Consequently, demonstration panels were constructed from grades 3, 4, and 5 common 25/32-inch lumber, and ponderosa pine veneer initially cut 3/10 inch thick, as previously discussed. Since particular interest had been expressed in using 4-foot veneer, the product was designed to span a single joist opening, with joists or beams placed on 4-foot centers. This would allow production of an 8-foot by 4-foot panel from 4-foot veneer, with the 8-foot panel dimension parallel to the joists. Tongue-and-groove matching on the unsupported or 4-foot ends was added to eliminate the need for blocking.

A finished flooring product, called Flex-floor, was developed by the Forest Products Laboratory several years ago to utilize low-grade softwood lumber. Flex-floor consists of a 1/8-inch hardwood face veneer cross laminated to a low-grade softwood backing of 5/8-inch lumber. The backing is grooved by sawing kerfs at frequent intervals to give the material a degree of flexibility. The product can be made in rather large sections, and can be V-grooved to simulate random-width

planking. It is particularly well suited to laying on concrete with an adhesive, a feature that should prove attractive in the concrete-slab type construction common in the Southwest.

Lumber-core flooring production

The lumber-core subfloor-underlayment panels constructed for demonstration and testing purposes were made 48 inches long and 40 inches long (rather than 8 feet) to facilitate manufacture and handling with laboratory equipment. Figure 26 illustrates the construction details of the panels.

The demonstration panels were constructed of low-grade 4/4 lumber remaining from earlier siding experiments, and the 3/10-inch ponderosa pine veneer previously produced from the low-grade veneer logs. The rough lumber-core stock was equalized and conditioned in a dry kiln to 7-9 percent moisture content, a level considered necessary for the plywoodlike type of construction involved.

The conditioned material was ripped random width to remove open defects, face jointed, and surfaced to 25/32-inch thickness.

Only open defects were removed in ripping; all sound defects such as knots, stain, and pitch streaks were allowed to remain in the material, as were small open defects such as borer holes, splits, and torn grain. A representative indication of material recovery could not be obtained, since the lumber being used was largely scrap and short boards of odd lengths, but an estimated surface area loss of 10 percent was sustained in ripping out open defects. This figure is generally representative of the loss that would be sustained in a production process.

The edges of the material were neither jointed nor surfaced unless an open joint greater than 1/16 inch resulted from laying up rough stock. Slightly loose or relieved joints provided between core stock pieces by the rough-sawn edges were considered desirable. Slightly open joints may help relieve glue-line stress as the panel changes moisture content in use.

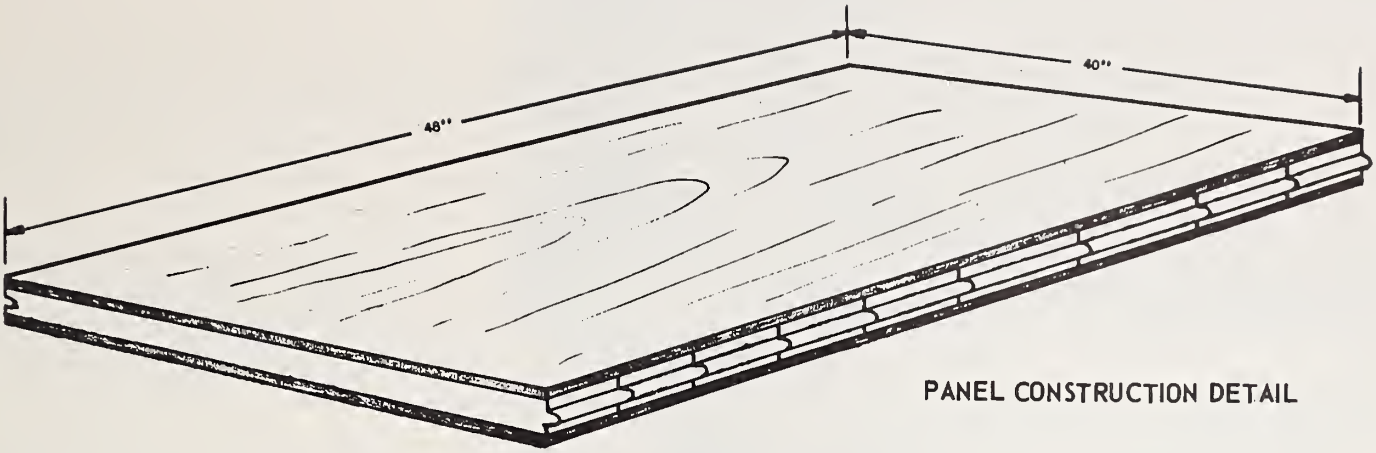
Face and back 3/10-inch veneer was sorted and clipped to rough panel dimensions. Panel faces were required to be free of open defects, except for splits or other small defects not exceeding 1/16 inch in width. Some face veneers with open defects were purposely included for subsequent patching tests with epoxy resin. Back veneer was allowed to contain open defects without restriction.

The panels were double spread with 70 pounds of a phenol-resorcinol adhesive per M square feet of glue line. The face and back veneer sheets were spread by hand roller while the core stock was passed through a conventional roller spreader. The laid-up panels were cold pressed at 150 pounds per square inch for a period of 12 hours or more (fig. 27).

The panels were then trimmed, and the few included open defects in face veneers were patched with an epoxy resin-wood flour patching compound. The panels were sanded by stages to determine the depth of sanding cut necessary to achieve a suitable face and thickness. The same amount was removed from both front and back veneers to retain a balanced construction. After removal of approximately 0.030 inch of material from each panel surface, the surfaces were judged suitable for the use intended. The finished panels measured 1.330 to 1.339 inches in thickness. On the basis of sanding allowance alone, a green veneer thickness of 0.275 inch rather than 0.300 inch appears adequate for production of a finished, touch-sanded, 1-1/4-inch panel.

The panels were sanded without difficulty, except that the high pitch content of the ponderosa pine plugged the closed-coat paper quickly. Again, this could be avoided through the use of open-coat paper and wide-belt sanders. Slight surface shelling visible on the face of some finished panels was attributed in part to repeated sanding necessitated by the partially plugged paper. The epoxy resin-wood flour patches used in several panel faces were sanded without difficulty and appeared to perform quite well.

The finished panels were end matched with the tongue-and-groove joint illustrated in



PANEL CONSTRUCTION DETAIL

CONSTRUCTION SPECIFICATIONS

(1) CORE STOCK 25/32-INCH S2S LOW-GRADE LUMBER: ONE SOUND FACE REQUIRED.

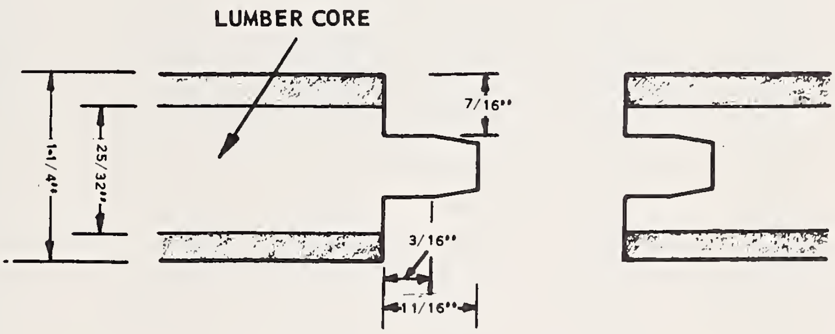
(2) PANEL FACE AND BACK 3/10-INCH VENEER: OPEN DEFECT ALLOWED IN BACK.

(3) DOUBLE SPREAD LOOSE CORE STOCK AND VENEERS: PHENOL RESORCINOL ADHESIVE, 70 LBS./M. SQ. FT.

(4) ASSEMBLE, COLD PRESS AT ROOM TEMPERATURE, 150-175 P.S.I., 12 HOURS OR MORE.

(5) TRIM, SAND TO 1¼-INCH FINISHED THICKNESS.

(6) TONGUE AND GROOVE PANEL ENDS PARALLEL TO FACE GRAIN.



TONGUE AND GROOVE DETAIL

Figure 26.--Manufacturing specifications developed for lumber core laminated flooring.

figure 26. This joint was designed to maintain flush surface alignment of the installed panels, and eliminate the need for blocking under panel end joints.

Lumber-core flooring tests and evaluation

Since the product was designed to be used in a load-bearing application, certain stiffness and strength properties were required for adequate performance. Stiffness and strength tests were performed on randomly selected panel sections 10-1/2 inches wide (fig. 28). Twelve such specimens were tested, with the results shown in table 15.

While the number of test specimens was insufficient for an extensive evaluation, the test results were rather constant. They indi-

Figure 27.--A preassembled lumber-core flooring panel is placed in the cold press.

Table 15.--Physical characteristics of three-ply lumber-core flooring made of low-grade ponderosa pine

Specimen No.	Depth	Width	Length	Moisture content	Specific gravity	Modulus of rupture	Bending stiffness, based on deflections-- Midspan between supports	Bending stiffness, based on deflections-- Between load points (pure)
	Inches	Inches	Inches	Percent		Lbs./sq.in.	Lbs.-inches² per inch of width	Lbs.-inches² per inch of width
1-2	1.336	10.41	48.09	10.5	0.403	4,000	154,600	156,000
3-2	1.336	10.42	48.10	10.7	.406	2,850	155,800	169,000
3-3	1.335	10.42	48.10	10.8	.409	3,310	160,400	173,000
3-4	1.332	10.39	48.10	10.3	.412	2,350	139,000	137,200
6-3	1.335	10.41	48.08	10.5	.405	3,250	133,500	141,000
6-4	1.333	10.43	48.10	10.5	.399	2,400	146,000	162,000
7-2	1.337	10.41	48.09	10.3	.422	2,440	152,000	171,000
7-3	1.339	10.42	48.10	10.4	.418	3,160	150,000	162,500
8-2	1.338	10.42	48.07	10.9	.404	3,000	158,000	175,000
8-4	1.329	10.43	48.10	10.7	.398	5,220	170,500	181,400
10-2	1.339	10.40	45.00	10.1	.421	2,500	113,200	120,500
10-4	1.330	10.43	45.02	10.3	.411	3,110	120,200	126,000
Average	--	--	--	10.5	.409	3,130	146,100	156,200

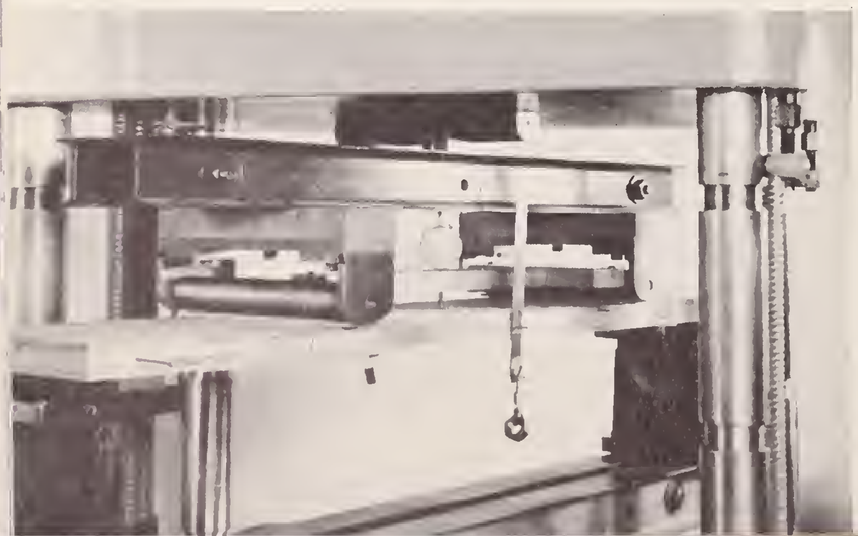


Figure 28.--A laminated lumber-core flooring panel positioned in a mechanical testing machine.

cate that both stiffness and strength are materially affected by the presence of knots and associated areas of short grain. The intergrown knots of ponderosa pine characteristically have associated with them large areas of irregular or short grain. All of the test specimens failed suddenly in the wood on the tension side, with no indication of gradual compression failure. Failure occurred in an area of short grain in each instance (fig. 29).

The test data indicate that the stiffness of the material is about 71 percent of that expected for the species, and modulus of rupture is about one-third of the average for the species. Furthermore, the brash tension failures indicate that the impact strength of the plywood would be quite low. As designed, the product is definitely unsuitable for the load-bearing uses intended. To be suitable, either redesign or stricter limitations upon allowable defect is necessary.

Redesign of the product was considered, on the basis of the strength and stiffness data developed in the tests. It was found that face plies 1/2 inch thick would be required to obtain the deflection characteristics of commercially available combination flooring products. An alternative design with acceptable deflection characteristics would require a 1-1/8-inch lumber core between 3/8-inch face veneers. Neither of these alternatives appears to be practically feasible. A more feasible alternative would be to reverse the 8-foot direction of the panel, so it would span two joist openings with the grain direction of the face veneers. This would require 8-foot face veneers, cut to the 3/10-inch thickness originally specified. The performance of the product used in this manner would still depend heavily upon the quality of face veneers used. It appears that any load-bearing application of the product will require stringent limitations upon allowable defect (especially knots) in the veneers used.

The basic concept of cross laminating thick veneers to lumber raises questions of dimensional stability, glue-line integrity, and face checking resulting from exposure to changing environmental conditions. To evaluate these factors, six 4-foot test specimens were cycled between 80 percent and 30 percent relative humidity conditions, at a temperature of 80° F. Moisture content, glue-line integrity, face checking, bow, and dimensional change were recorded after exposure for 4 months to each set of conditions.

Panels in equilibrium at 80 percent relative humidity rose from 7 percent to 13.5 percent moisture content. No delamination or face checking occurred. The panels exhibited an average bow of 0.02 inch, and maximum of 0.04 inch, over a 42-inch span. The panels did, however, develop a slight waviness associated with the grain of the core stock. The waviness was sufficient to cause misalignment of the tongue and groove on unjointed panels. As a result, a longer, more tapered tongue was incorporated in the design (see fig. 26).

The panels increased 1.9 percent in thickness and 0.12 percent in length, under 80 percent relative humidity conditions. The 0.12

Figure 29.--These laminated flooring test specimens show tension failure in areas of short grain.

percent increase in length would result in an increase of about 1/16 inch over a 4-foot span, well within acceptable limits.

The same panels in equilibrium at 30 percent relative humidity dropped to 6 percent moisture content. No delamination occurred. An average of six small checks, none exceeding 1/32 inch in width, formed on the panel faces. Checks of this size are quite acceptable. Bow dropped to a maximum of 0.025 inch over a 42-inch span. Waviness and associated tongue and groove distortion disappeared, for all practical purposes. Panel thickness and length returned to within 0.1 percent of original dimensions.

The single significant limitation indicated by the tests was the tendency of panels to develop short waves at high humidity. Limiting the width of core stock to a maximum of perhaps 6 inches should reduce this tendency to allowable limits.

The design concept used in developing this product appears to be entirely valid. With the exception of the strength and stiffness deficiencies induced by the quality of material used, the product appears to perform satisfactorily. As previously pointed out, strength and stiffness deficiencies seriously curtail the use of the product in load-bearing applications. Potential uses for the product will depend heavily upon the quality of face veneers available for use.

Flex-floor finished flooring

The finished flooring product previously described, Flex-floor, is especially adapted to laying over concrete floors, although it can be laid over any type of subfloor. Its adaptability to concrete subfloors should prove particularly attractive in concrete slab-type construction.

A sufficient quantity of Flex-floor was manufactured to demonstrate the possibility of using low-grade ponderosa pine lumber as backing material. Chestnut oak flitches were sliced to provide face veneer for the Flex-floor. The veneer was sliced 1/7 inch thick to provide allowance for drying shrinkage, press compression, and sanding. In addition, some rotary-cut birch veneer was used on a portion of the flooring. Trimmings from the grade 3, 4, and 5 common ponderosa pine lumber provided for overlaying were used for backing material.

The rough 4/4 backing stock was placed in a dry kiln for equalizing and conditioning to 7-9 percent moisture content, then ripped to remove open defects, face and edge jointed, and surfaced to 5/8-inch thickness. All sound defects were allowed to remain in the stock as were slight open defects, such as splits, borer holes, and torn grain.

Since the material being used was principally small stock of odd dimensions, a representative volume recovery determination could not be obtained. Less than 10 percent of the initial surface area was lost in ripping out open defects, however.

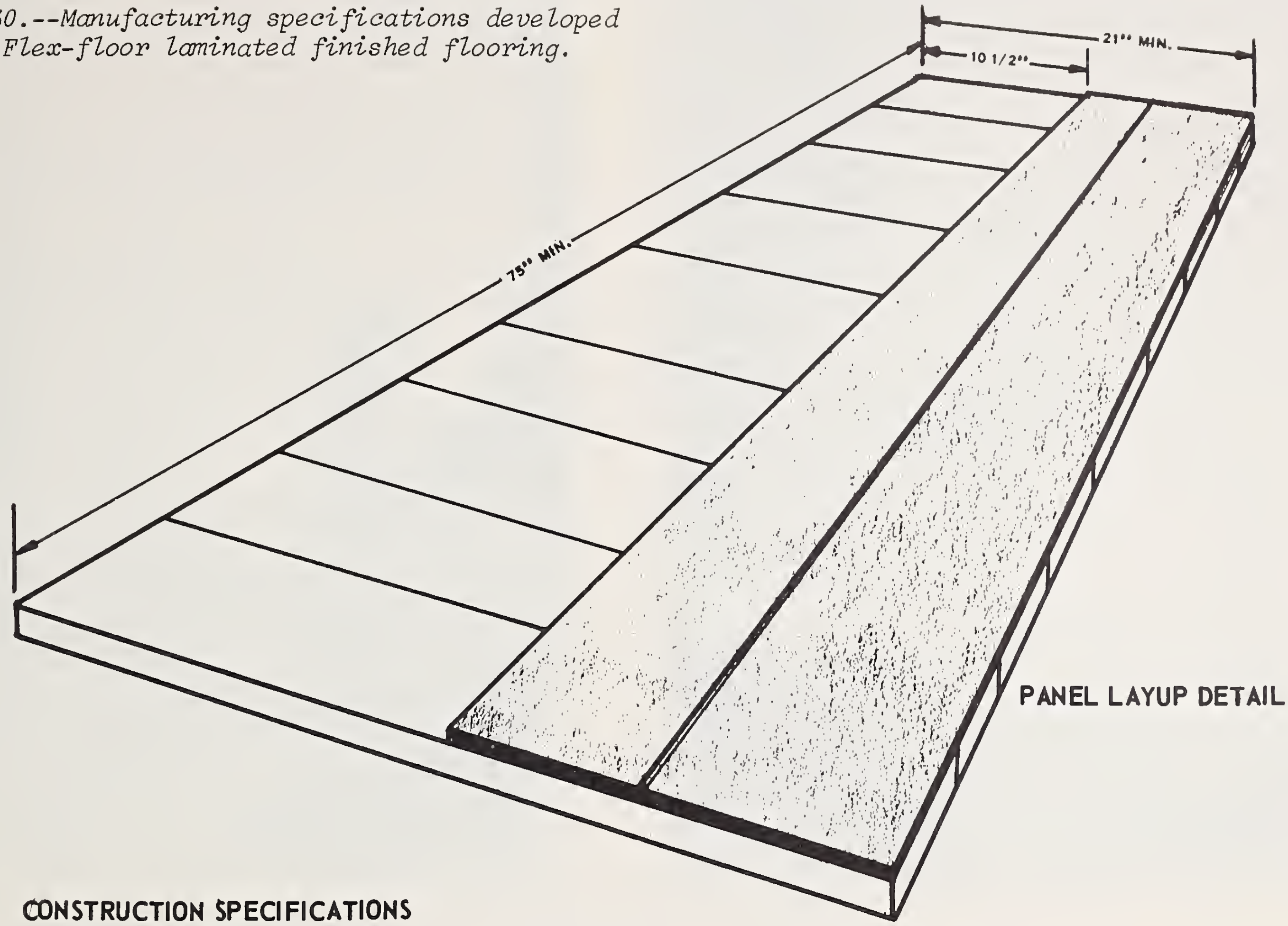
The base stock was laid up in rough panels 21 by 75 inches (fig. 30), which yielded two 9- by 72-inch units of finished flooring.

The double-width panels were bonded with an acid-catalyzed phenol-resin adhesive, with a single spread of 55-60 pounds per M square feet of glue line. The base stock was laid out loose on a metal caul, and one edge was aligned with a straightedge. The adhesive was applied to the face veneer by hand roller, and the veneer was placed on the loose panel of base stock (fig. 31). The laid-up panels were cold pressed at a pressure of 150-175 pounds per square inch for 12 or more hours.

After removal from the press, the cured panels were face sanded lightly to provide a suitable surface for finishing, then ripped down the center line to form two single units of flooring. The flooring was trimmed and edge jointed, then end and edge matched with standard 1/4-inch tongue and groove, which left a finished face dimension of 9 by 72 inches.

The flooring face veneer was V-grooved in a random-width pattern to simulate random-width planking. The groove pattern was positioned on the flooring so that a V-groove coincided with each edge glue line, to provide

Figure 30.--Manufacturing specifications developed for Flex-floor laminated finished flooring.



CONSTRUCTION SPECIFICATIONS

(1) LOW-GRADE S4S 5/8-INCH BASE STOCK LAID UP LOOSE IN 21-INCH BY 75-INCH PANELS.

(2) HARDWOOD 1/7-INCH FACE VENEER SINGLE SPREAD WITH PHENOL RESIN ADHESIVE, 55-60 LBS./M. SQ.FT.

(3) ASSEMBLE, COLD PRESS AT ROOM TEMPERATURE, 150-175 P.S.I., 12 HOURS OR MORE.

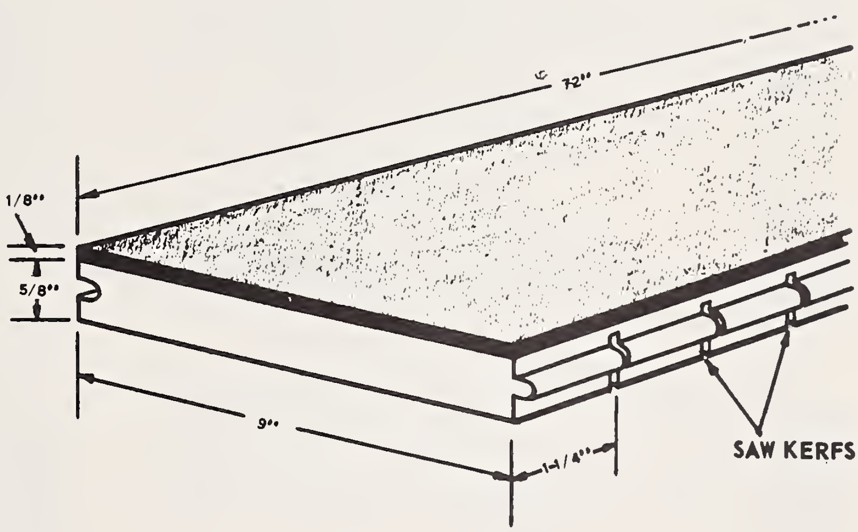
(4) FINISH SAND FACE VENEER, RIP PANELS DOWN CENTER, TRIM, EDGE-JOINT FLOORING WIDTHS.

(5) END- AND EDGE- MATCH WITH TONGUE AND GROOVE.

(6) SAW KERF BASE MATERIAL AT 1¼-INCH INTERVALS.

(7) CHAMFER FACE EDGES AND ENDS, AND VEE-GROOVE FACE VENEER AS DESIRED.

(8) PREFINISH AS DESIRED.



CONSTRUCTION DETAIL

a logical break between grain patterns. Remaining V-grooves were allowed to fall at random in single veneer strips.

The base stock was grooved with 1/8-inch saw kerfs on 1-1/4-inch centers across the direction of face veneer grain (see fig. 30).

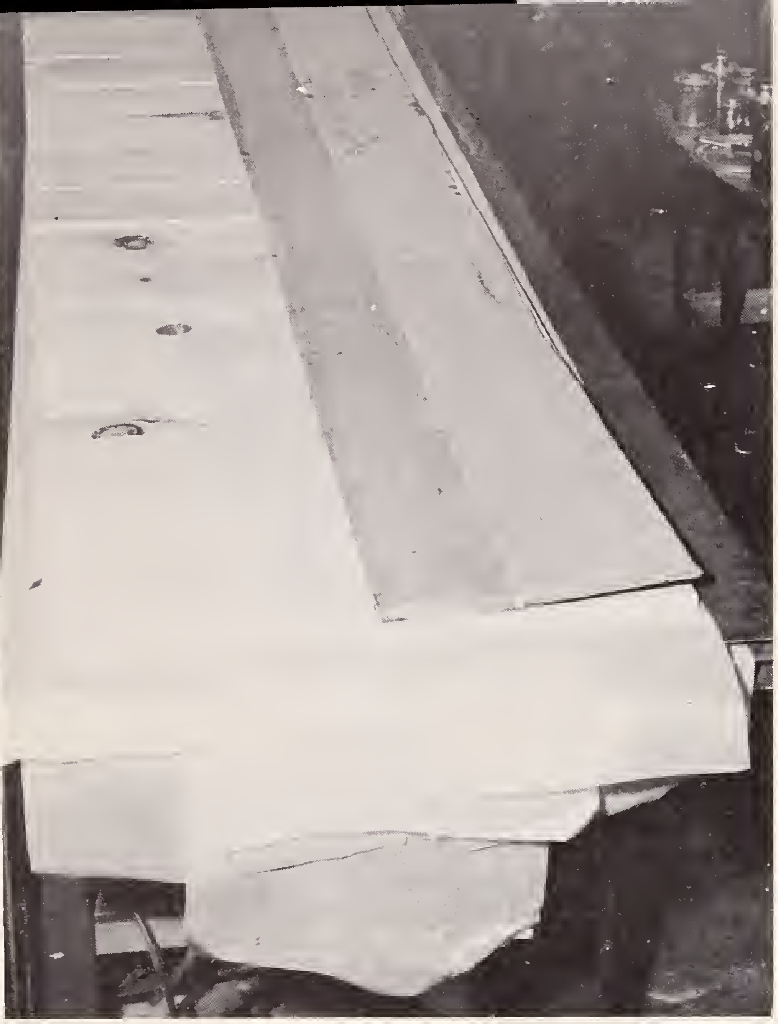


Figure 31.--Base stock for Flex-floor was laid up in double flooring widths; hardwood face veneer was then spread with adhesive and applied to the base stock.

Figure 32.--Flex-floor laid over a standard plywood subfloor. The reversed section of flooring shows the flexibility of the kerfed low-grade ponderosa pine base stock.

The kerfs were cut 9/16 inch deep, to within 1/16 inch of the face veneer.

The completed flooring was prefinished by filling, sealing, and waxing (fig. 32). Since the flooring is of uniform thickness, edge and end matched, and in large pieces, it can be prefinished without difficulty.

Flex-floor can be produced in a wide variety of sizes and styles, with a minimum of production detail. Its production can be readily integrated with other cut stock and laminating processes such as overlaid product manufacture. For production of Flex-floor in the Southwest, hardwood face veneers would have to be "imported"; this is common practice in the plywood industry, however.

PLANT EQUIPMENT AND CAPITAL INVESTMENT REQUIREMENTS

The plant equipment and investment required to manufacture a product in economically practical quantities depends a great deal upon the "minimum economic size" of operation for the particular industry. Generally, the minimum economic size of operation is not fixed, but varies with the production process, production and marketing conditions, and external cost factors. Qualifying assumptions are necessary. There is a wide range of operating modes and equipment for any production operation. Most items of heavy equipment are available in a variety of sizes, styles, and capacities. Some manufacturing processes, such as sawmilling, are accom-

plished with rather uniform standardized items and groupings of equipment. Even in such standardized processes, however, a wide range of automation and equipment capacity is available that materially affects capital investment.

To determine the equipment and investment needed for a plant, it is necessary to establish an operational design technically and economically suited to local conditions. The investment needed to establish an operation varies with:

1. Size and quality of raw material.
2. Degree of integration with existing industries or processes.
3. Local availability of power and labor.
4. Effect of labor costs upon degree of automation desired.
5. Relative location with respect to raw material and markets.

Equipment and investment estimates can furnish only broad guidelines, subject to wide variation. For any given type of product, however, there exists a minimum economic size of operation dictated by the nature of the process and the minimal equipment required to produce at all. Most manufacturing industries recognize such a minimum plant size. This minimum size tends to become larger as the industry grows and the process becomes more intricate and refined. It is with such a "minimum economic size" in mind that the following equipment requirements and investment costs are presented.

For items of equipment that are relatively standardized, an average installed cost is shown. Some items of equipment, however, are available in such a wide range of varieties and sizes that an "average" cost becomes meaningless. For such equipment, no cost is shown. It must be emphasized that the plant equipment costs presented are averages, are based upon the minimum economic size of efficient plant generally recognized by industry, and are subject to frequent change.

Veneer and Plywood

The following equipment requirements are considered minimum for a softwood plywood plant that utilizes 4-foot veneer bolts to produce approximately 25 million square feet (3/8-inch standard) per year for a specialized product such as underlayment, in a 4-foot by 4-foot panel size:

Plant equipment, softwood plywood, 4-foot by 4-foot panel

Quantity	Equipment	Installed cost
--	Block and log handling	$ 25,000
3	Heating vats	20,000
--	Block handling to lathe	5,000
1	Lathe, 54 inches	40,000
1	AC-DC lathe drive	12,000
--	Veneer conveyor system and grading table	25,000
2	Automatic green clipper, 54 inches	14,000
1	Scrap conveyor from lathe	6,000
1	Automatic knife grinder, 54 inches	6,000
1	Roller conveyor veneer dryer	120,000
1	Automatic moisture detection system	6,000
1	Dryer unloader conveyor	5,000
1	Dry sizing clipper, 54 inches	2,000
1	Patch blanking saw	2,000
1	Veneer patcher with gravity rolls	13,000
1	Patcher scissors lift	1,000
1	Veneer jointer, 54 inches	8,000
1	Tapeless veneer splicer	6,000
1	Glue mixer	3,000
1	Hot plate press, multiple opening, 4' x 4'	60,000
1	Wide belt sander	25,000
1	Hydraulic elevator at hot plate press	6,000
2	Fork lift trucks	18,000
1	Glue storage tank	11,000
--	Misc. hand trucks, pellets	1,000
--	Building with 60,000 sq. ft. of floor space, equipped with sprinkling system, lighting, concrete floor and machine foundations, electrical wiring, and steam piping to vats and press	--

Plant equipment, softwood plywood, 4-foot by 4-foot panel

Quantity	Optional equipment	Installed cost
1	Automatic block-centering device and lathe charger	20,000
1	Core conveyor from lathe	5,000
1	Scrap conveyor from clipper	8,000
1	Wet veneer chipper	24,000
1	Core chipper	16,000
1	Blow system, chippers to car	16,000
1	Dryer feeder	24,000
1	Dryer unloader	14,000
1	Hot press load trim band saw	1,000
1	Air compressor and tank	8,000

A plant of this size would probably prove too small for production of standard products such as sheathing, in a highly competitive market. Most of the softwood plywood plants recently constructed to produce such standard products have been designed for annual output capacities 3 to 4 times greater than this, and have entailed investment costs of from 2 to 10 million dollars.

The optional equipment listed is considered desirable as an addition to the minimal equipment. Its use could materially reduce labor costs, and more fully realize the capacity potential of the basic equipment.

Laminated Beams

If vertical lamination of low-grade lumber to produce construction beams can be integrated with an existing sawmill operation, the amount of equipment initially required will be materially reduced.

In defining minimum equipment requirements for a laminating operation, it was assumed that an existing kiln would be used to reduce the moisture content of the material to 8-10 percent. It was also assumed that the material would be surfaced on two sides with existing planer facilities, and would not be surfaced again prior to laminating. Tests indicate this would be feasible. The beams are designed to be constructed of full-length laminations; therefore, scarf-joint and finger-joint equipment is not essential, although it might be advantageous.

The suggested minimum economic size plant should be able to process 4,800 board feet of material per 8-hour day. The equipment considered necessary for this size of operation is listed in the following tabulation:

Plant equipment, beam lamination

Quantity	Equipment	Installed cost
1	Glue spreader, 18 inches	$ 1,600
200 ft.	Roller bed, 14 inches	500
200 ft.	Screw clamps and carrier run	5,000
1	Compressor and tank	1,000
2	Pneumatic wrenches	500
1	Glue mixer	500
200 ft.	Jigs to retain output under pressure, 4 sq. ft. cross section	4,000
1	Overhead block and tackle, overhead rail	5,500
1	Cabinet surfacer or heavy duty jointer	6,000
--	Hand sanders, drills, saws	800
--	Misc. brushes, benches, tables, tools, equipment	1,400
--	Building with 10,000 sq. ft. of floor area, concrete floor	--

In addition, if the beams are subjected to nondestructive stiffness testing, the cost of installing and using such equipment must be considered. An end coating such as paraffin should be applied to the ends of beams prior to shipment; however, for limited production such end coatings can be applied effectively by hand.

The equipment indicated above is in general specifically adapted to laminated beam production. Greater production versatility could be achieved, however, by using some less specialized equipment with a wider range of product capabilities. The following section is concerned with equipment suited to a variety of cold press and laminated products, and indicates how beam production can be integrated with the production of other products.

Cold Press Overlaying and Laminates

The production of cut stock, end-and-edge glued overlaid products, or laminated flooring products can be integrated quite effectively with a sawmill operation. A wider range of end products provides the means for utilizing varying qualities of material, which can in turn lead to reduced unit costs in overhead, logging, and service functions. A single sales organization can also effectively develop sales of products closely related in end use.

The basic items of equipment used in producing many secondary mill products are highly versatile and applicable to the production of a wide range of products. For example, cut stock, end-and-edge glued overlaid products, laminated flooring products, and small laminated beams can be produced with minor variations of the same basic equipment. This provides a high degree of production versatility, an important feature in patterning production to meet changing market demands.

In view of the interrelated equipment requirements, the production of overlaid siding products and laminated flooring products can be considered as a single enterprise. Furthermore, the equipment involved also provides some capability to produce laminated beams. Mixed production or frequent production changes from one type of product to another would probably prove impractical since different adhesives, spreader roll configurations, and equipment preparations are involved. A basic capability to change from one type of product to another, in response to market changes or other criteria, however, is invaluable. The basic production line and equipment can be converted from one product to another relatively quickly and inexpensively.

In considering the minimal equipment necessary to produce overlaid and laminated products, preference was given to versatile types of equipment. The equipment required to produce overlaid siding products and laminated flooring products is listed in table 16. Laminated beams, covered separately in the previous section, are again included here, since the basic equipment also provides some capability for their production. The range of versatility associated with each item of equipment is indicated.

In addition to the equipment listed, handling and packaging equipment not already available must be considered.

The inherent versatility of the equipment can be further enhanced by a plant layout that minimizes rearrangement for specific products. Figure 33 presents in schematic form a production flow system designed to utilize the equipment listed, and facilitate production of any of the products considered.

Particle Board

Low-quality ponderosa pine material can be used in the production of particle board. The test boards had highly satisfactory dimensional stability and strength characteristics. Boards of either conventional or special construction appear worthy of consideration.

Commercial particle boards are currently produced by a rather large number of firms, however, and competition in the open market is keen. The captive particle board operation, in which the board is used in the manufacture of a finished product, provides a potential exception. Any contemplated particle board operation should be preceded by, and based upon, a careful survey and analysis of marketing potential.

Particle board products can be produced through several dissimilar processes. The primary commercial processes for making particle board are (1) multi-platen press, (2) vertical extrusion press, and (3) horizontal extrusion press. The equipment necessary for production differs widely between processes; in addition, equipment suitable for any single process is subject to wide variation. Consequently, no attempt is made to present detailed minimal equipment and capital investment requirements for particle board production.

Several generalized "rules of thumb" for minimum economic size of operation, and associated capital investment, have developed. A commonly suggested minimum level of production for a multi-platen flat press installation is 40 tons of dry material per day, or approximately 26,000 square feet of board

Table 16. --Plant equipment, overlaying and laminating

Quantity	Equipment	Installed cost	Combination siding-sheathing	Resawn beveled siding	Flex-floor	Laminated-- Lumber core flooring	Laminated-- Beams
		Dollars					
1	Straight line rip saw	5,000	x	x	x	x	
--	Rip and crosscut power feed cut-up saw	3,000	x	x	x	x	
--	Finger-jointing equipment (tongue and groove optional)	--	x	x			
--	End and edge gluing equipment	--	x	x			
--	Plugging equipment, 3-inch capacity (optional)	1,000	x	x	x	x	
1	Single or double surfacer, 52 inches	10,000	x	x	x	x	x
1	Roller coater, 52 inches	2,000	x	x			
1	Glue spreader, 52 inches	3,000	x	x	x	x	x
1	Cold press, side loading, 42-inch opening, 50 by 150 inches, compressed air or hydraulic actuation	10,000	x	x	x	x	
--	Press I-beams, cauls, equipment	2,000	x	x	x	x	
--	Rip and crosscut trim saws, table (finished end)	3,000	x	x	x	x	x
1	Double spindle shaper with power feed (single end tenoner, optional)	6,000	x	x	x	x	
--	Preservative dipping troughs and conveyor system	1,000	x	x			
1	Belt sander	6,000			x	x	
--	Building with 20,000 square feet of floor area, concrete floor	--	x	x	x	x	x
Additional equipment required for specific products:							
1	Vertical band resaw, adjustable tilt	10,000		x			
1	Face groover, simulated planking	1,000			x		
1	Gang saw, power feed (kerfing base stock)	5,000			x		
--	Face veneer finishing equipment	2,000			x		
1	Veneer jointer, manual feed[1]	5,000			x		
1	Veneer edge-gluer[1]	10,000			x		
--	Beam clamps and clamp carrier	5,000					x
1	Jointer, power feed	3,000					x

[1] Veneer jointing and edge-gluing equipment will be unnecessary if hardwood face veneers for Flex-floor are purchased pre-sized.

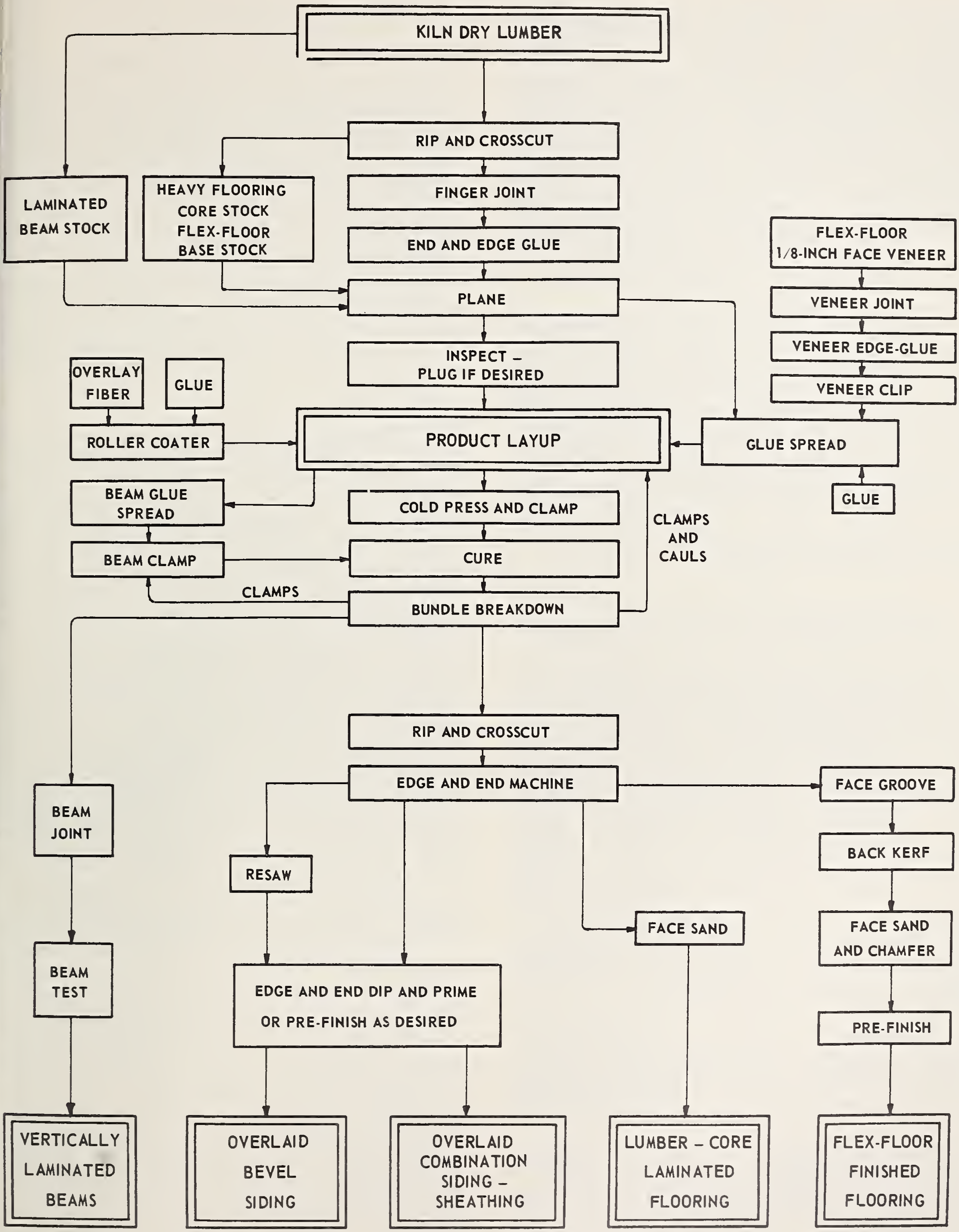


Figure 33.--A basic production flow design for the manufacture of both overlaid and laminated products. Designed by Bruce G. Heebink, Engineer, Forest Products Laboratory.

per day (3/4-inch basis). The capital investment for such a plant has been estimated to involve $20,000 to $25,000 per ton-day of capacity, or about 1 million dollars minimum. Extrusion-process plants, which can generally operate economically on a somewhat smaller scale and involve less capital investment per ton of capacity, would perhaps entail a capital investment of one-third to one-half this amount. Again, these values are broad estimates, and are subject to considerable variation under differing circumstances.

Investment requirement alone should not be the sole criteria for comparing flat-press and extrusion processes. The products of the two processes differ considerably. For most uses, extruded boards have poorer physical characteristics than flat-pressed boards. In addition, flat-press processes provide more latitude for engineering boards to particular specifications, such as multi-layer boards. Flat-pressed particle boards make up the bulk of current production.

FURTHER UTILIZATION POTENTIAL

The current study has by no means exhausted the range of possible new uses for low-grade ponderosa pine in either log, lumber, or residue form. The products specifically considered were chosen for their apparent adaptability to the immediate problem, plus professed industry interest in them. Generally speaking, they represent either means of avoiding production of low common grade lumber, or means of effectively using it after it is produced. Only incidental attention was given the utilization of sawmill residue materials, a prime factor in realizing better utilization of the resource.

An account of utilization potential for low-grade ponderosa pine timber would not be complete without mention of some of the additional utilization possibilities for the species:

1. The fabrication of selected wood products for local markets.
2. Means of utilizing mill residues currently wasted.
3. Fiber-board production in conjunction with current pulp operations.
4. Chemical conversion.

Wood Product Fabrication

The fabrication of wood products for local markets offers unique advantages for sawmills of practically any size. For many rough wood products such as boxes, bins, pallets, and snow fence, very little additional equipment and capital investment are required. Most such products can effectively utilize the lower grades of common lumber. In addition, secondary manufacturing or processing beyond the lumber stage adds appreciably to the labor force sustained and the total product value achieved, which augments area or community well being.

In the Southwest, a potential market exists for agricultural bins and boxes, and industrial pallets. The citrus fruit and truck-garden industry in the Southwest uses paperboard and plastic final packaging, but depends extensively upon wooden bins and crates for picking, handling, and processing. Bin pallets (combination bin and pallet) are commonly used in citrus groves as containers for transporting, storing, and processing fruit. Bin pallets are normally rather heavily constructed, and designed for a life expectancy of several seasons. Acceptable agricultural bin pallets can be constructed from low-quality material, through selective cutting and selection of component parts. Smaller wooden boxes and crates are also widely used in the fruit and truck-garden industry.

Practically all manufacturing and distribution industries handle materials and products with forklifts, and most have developed a "palletized" system of material storage and transfer. Because pallets can be produced from the lower common grades of lumber and require little specialized equipment or skills, their production is easily adapted to either manual or automated assembly.

Other manufactured products that can easily be integrated with sawmill operations include fence lath, wire-bound snow or ornamental fence, surveyor's stakes, and industrial crating. The manufacture of such products may be particularly attractive to smaller operations, since very little additional capital investment is required.

Residue Utilization

Much of the residue from lumbering operations in the Southwest is not currently utilized. The marked improvement brought about by the establishment of a local market for pulp chips is still insufficient to absorb a high proportion of the total available supply. A number of products (other than the particle boards previously discussed) provide potential outlets for residue: charcoal, briquetted fuel, natural wood fuel, soil conditioning and mulching materials, and such specialty products as barn and feed-lot bedding, wood flour, and sweeping compound.

The market for charcoal has gained strength in recent years, due primarily to increased interest in outdoor cookery. This is particularly true in areas such as the Southwest with moderate year-round weather. The development of continuous carbonization retort methods of charcoal production make feasible the use of hogged residue and miscellaneous wood fines. Bark can be included with other wood material if it is reduced to comparable size before processing. Since continuous retort processes produce fine charcoal, briquetting is necessary. Briquetted charcoal is somewhat favored over lump charcoal by both dealers and consumers, however, and would enjoy some market advantage. Although the capital investment in continuous carbonization and briquetting equipment is substantial, a cooperative development among a number of mills might be considered. The recently developed gas recycle retorts operating on either short-length round or slab wood provide an additional important means of efficient production.

High-density briquetted fuel, produced from sawdust and wood or bark fines, also presents residue utilization potential. Ponderosa pine has proven to be a preferred species for wood briquets from sawdust or other fine material. Wood particles are self bonding when briquetted under high pressure at elevated temperatures, and thus require no added binder. High-quality briquets can also be produced from bark alone. To develop necessary strength and hardness in wood briquets, current practices require that the material be quite dry, preferably from 6 to 10 percent moisture content. Various types of high-temperature driers or short-cycle flash driers will reduce the moisture content of waste material. Several wood-briquetting plants in the United States use high-pressure molding machines to produce pressed logs suitable for fireplace and similar use. In addition, there are a number of extrusion-type briquetting machines in operation that produce pellets or stoker-size briquets.

Sawdust, shavings, and hogged wood or bark have received attention as soil conditioning and mulching materials. These materials have essentially no fertilizer value unless they are composted. When added to the soil, however, they do increase moisture retention, induce better aeration and tilth, and supplement native humus. When used as a mulch, wood materials reduce evaporation, retard erosion, and aid in weed control.

Untreated raw-wood residues used as mulches or conditioners will compete for available nitrogen in the soil as they decompose, and can create a nitrogen deficiency. Consequently, most commercially prepared soil additives from wood are either composted or chemically treated to add nitrogen. Bark or sawdust may be composted with corral or feed-lot manure to satisfy the nitrogen requirement. Aqueous ammonia and micro-organism inoculants are also sometimes added, and greatly speed composting. Ponderosa pine bark seems particularly well suited to this use, since it hammer-mills more uniformly than do fibrous barks.

In areas in which feedlots and livestock enterprises are common, wood chips and shavings may be salable as bedding material. Commercial shaving balers simplify packaging, storing, and handling the material. A residual benefit may be derived from the natural composting of the material while in use as bedding.

Other potential uses for selected mill residue and sawdust include such products as wood flour and sweeping compound. Ponderosa pine residue appears to be well suited to the production of wood flour, since it is not strongly acid, is light in color, and relatively free from excessive pitch. Although the mar-

ket for wood flour is rather small, demand is probably increasing in newer industrial areas such as the West Coast. Wood flour, consisting of finely divided wood particles about the size of cereal flours, is used as a filler in linoleum, explosives, and plastics. It is also used to produce molded wood products, and as a cleansing agent, a mild abrasive, and a filler in some flues and cements. Wood flour may be reclaimed from sander dust or sawdust, or may be manufactured. A variety of wood-flour mills are in use, including attrition mills for sawdust-size material and hammer mills or crushing mills for larger residues. Oversize particles are air separated or mechanically screened from the flour. The specifications for wood flour are rather exacting for most uses, and require close quality control.

Sawdust is commonly used as an absorbent in floor sweeping compounds, which are usually composed of sawdust, clean sand, salt, and oil or water-wax emulsion. Oils are used in compounds designed for cement, terrazzo, or wood floors, while wax emulsion is used in compounds for linoleum, rubber, and asphalt floors. In addition, dyes and scented oils are often added. Sweeping compound can easily be mixed in a revolving drum or concrete mixer, and discharged directly into marketing containers.

Fiberboard Products

The production of fiberboard or hardboard products can utilize extensive quantities of low-quality material in log or residue form. Since the initial processing of raw material can be essentially that used in producing groundwood pulp, fiberboard production could be integrated with existing groundwood pulp operations. Fiberboard production has been highly developed, however, and competition in the open market is intense. Fiberboard product potential will depend heavily upon the strengthening of established markets and development of new markets.

Fiberboard production requires pulping equipment, Fourdrinier-type forming machines, multi-platen hot presses, and continuous driers, most of which are designed for high-capacity production. Consequently, minimal capital investment is high and large-capacity installations are common. It has been estimated that a plant designed around one multi-platen press (4-foot by 16-foot, 20-opening) must have available at least 90 tons of raw material per day.

Raw material for fiberboard is pulped by mechanical grinding, steaming, chemical pulping, or defibrating. Mechanical grinding is the most common method employed in producing insulating board. Most hardboard is produced by pulping wood in chip form. In conventional or wet-felting processing, the washed fibers are suspended in a slurry and deposited on a Fourdrinier wire or special forming machine. Hardboard is produced by hot pressing and drying the fiber mat. Insulation board is produced by drying the mat in a continuous dryer, without further hot pressing. Medium-density building board is produced by adding a binder to the fiber mat and hot pressing to a relatively low density.

In a process variation known as air-felting the fibers are partially dried, conveyed in air suspension, and formed into mats for hot pressing. A resin binder is added in the dry process.

For each step in fiberboard production there is a wide variety of techniques and equipment available. The processes present definite possibilities for improvement through innovation. New methods of raw material preparation, new handling methods, and new production techniques could easily improve the existing production cost structure.

Chemical Conversion

Research on the chemical conversion of wood and bark residues indicates that such conversion (although still largely in the development stage) is of potential importance. Several notable examples of successful chemical wood product operations do exist, however. These include the rayon industry, the charcoal industry, the naval stores and tall-oil industry, and the use of wood-derived chemicals in plastics and photographic films. Bark extractives currently yield phenolic de-

rivatives useful as waterproof adhesive components, and tannins valuable as deflocculants in drilling muds.

Processes that may be useful in the economic recovery of industrial chemicals include fermentation, hydrolysis, and hydrogenation. Hydrolysis of wood will convert the hemicellulose and cellulose fractions to sugars, notably xylose and glucose. Wood sugars can be converted into a host of chemical products, including molasses and yeast. Xylose can be converted to furfural, a chemical used in the production of nylon. Glucose can similarly be converted to levulinic acid and other compounds potentially valuable as industrial chemicals. Other ways in which glucose can undergo further chemical conversion include fermentation to ethyl alcohol, microbiological conversion to food yeasts or glycerol, and hydrogenation to obtain glycerol and other polyhydric alcohols.

Wood hydrolysis has been used to produce sugars that have been concentrated to yield wood-sugar molasses on a pilot-plant basis. Wood-sugar molasses is potentially valuable as an animal feed. The feeding tests conducted indicated that wood-sugar molasses was the equivalent of black-strap molasses as a carbohydrate feed supplement. Minor adverse characteristics, such as a tendency for solids to form in the molasses during storage, can be corrected by modification of the production methods employed. Successful production of wood sugars depends more upon economic than technical considerations.

The growing trend toward integrated utilization of wood resources favors continued development of a chemical conversion industry. Chemical conversion can provide the last step in an integrated operation by utilizing material that is unsuited to other more demanding uses.

APPENDIX A

Ponderosa Pine Test Materials

Test materials for the study were selected from the lower grades of logs and lumber found in Arizona and New Mexico sawmills. Table 17 indicates the quantity and grade of test lumber provided. The test logs and special test materials are described below:

Item	Quantity	Description
Grade 5 sawlogs for peeling	4	10 ft., 13-21 inches diameter, 540 b.f. Scrib. Dec. C, typical grade 5 logs.
Grade 6 sawlog for chipping	1	12 ft., 18 inches diameter, 160 b.f. Scrib. Dec. C, typical grade 6 log.
Planer shavings	300 lbs.	Lower head, 1/16-3/32 inch cut; head angle, 63°; knife rake angle, 15°-20°. Knife cuts per inch, 16 at 180 f.p.m.; 9 at 325 f.p.m.
Debarked slabs	500 lbs.	--

Table 17. --Ponderosa pine test lumber

Width (Inches)	Length	Grade 3	Grade 4	Grade 5
	Feet	- - Board feet - -		
4/4 Common, rough:				
12	12	96	120	108
10	12	125	106	87
8	12	96	104	112
6	12	42	36	42
4	12	40	36	44
Total		399	402	393
4/4 Common, S2S:				
10	16	253	266	239
6/4 Common, rough:[1]				
12	12	90	72	90
10	12	72	72	72
8	12	60	60	60
Total		222	204	222

[1] 6/4 Common lumber substituted for 5/4 Common originally specified.

The saw logs designated for peeling were converted to eight 52-inch test bolts, for veneer and plywood production and test purposes. Each of the eight bolts was diagramed before peeling. Table 18 provides a description of each of the test bolts.

Table 18. --Veneer test bolt description

Bolt No.[1]	Diameter		Pith eccentricity[2]		Knots		Other characteristics
	Small end	Large end	Small end	Large end	Number	Size range	
	- - - Inches - - -					Inches	
2-2	$19\frac{1}{2}$	$20\frac{1}{2}$	$1\frac{1}{2}$	2	6	2 to 10	Spiral grain evident; few encased knots; intergrown bark pocket.
3-1	$13\frac{1}{2}$	$14\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	6	$\frac{1}{2}$ to 4	Compression wood evident in sapwood in one-quarter of bolt; some encased knots.
4-1	$17\frac{1}{2}$	18	0	$\frac{3}{4}$	12	$\frac{1}{2}$ to 3	Heart rot evident in center of bolt; some encased knots.
5-1	21	$21\frac{3}{4}$	1	1	7	$\frac{3}{4}$ to $3\frac{1}{2}$	Some intergrown bark; several encased knots.
2-1	$20\frac{1}{4}$	22	2	$2\frac{1}{2}$	11	2 to $6\frac{1}{2}$	Most knots intergrown; few encased.
3-2	$13\frac{1}{4}$	$13\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	5	1 to 2	Compression wood evident in sapwood in one-quarter of bolt; some encased knots
4-2	$17\frac{1}{2}$	18	$\frac{1}{2}$	1	12	1 to 4	Heart rot evident in center of bolt; some encased knots.
5-2	21	21	$1\frac{1}{4}$	$1\frac{3}{4}$	4	$\frac{3}{4}$ to 3	Knots grouped--two-thirds of bolt surface clear; some encased knots.

[1] Bolts 2-2, 3-1, 4-1, and 5-1 were designated for production of 1/7-inch veneer; the remaining four bolts were designated for 3/10-inch veneer.
[2] In rotary cutting, all bolts were chucked in their geometric center.

APPENDIX B

Glossary

The terms employed in this publication are in general well known to one or more sectors of the wood utilization industry. Some terms, however, may be unfamiliar to those acquainted primarily with lumbering and associated activities. Terms that may warrant general definition, or specific definition regarding their particular use in this publication, are included in this section.

Board - an item of lumber less than 2 inches in nominal thickness.
- a. 4/4 lumber - lumber with a nominal thickness of 1 inch, and finished thickness of 25/32 inch.
- b. 5/4 lumber - lumber with a nominal thickness of 1-1/4 inches, and finished thickness of 1-5/32 inches.
- c. 6/4 lumber - lumber with a nominal thickness of 1-1/2 inches, and finished thickness of 1-13/32 inches.

Bow - distortion of a board characterized by deviation from flatness lengthwise.

Brashness - a condition in wood that causes it to break suddenly and completely across the grain when bent slightly.

Casehardening - a condition of stress in wood in which the outer fibers are under compressive stress and the inner fibers are under tensile stress.

Check - a lengthwise separation of wood, usually extending across the rings of annual growth; e.g., checks may extend radially from the pith or center of a log.

Compression failure - localized buckling of fibers produced by compression of wood along the grain beyond its proportional limit.

Compression wood - abnormal wood formed on the lower side of branches and inclined trunks of softwood trees; characterized by relatively wide, eccentric growth rings and excessive longitudinal shrinkage.

Conditioning treatment - a controlled high-temperature, high-relative-humidity kiln condition applied to bring about a uniform moisture distribution in lumber and relieve drying stresses.

Crook - distortion in which the edges of a board deviate from a straight line end to end.

Crossbanding - the inner plies of plywood that are oriented perpendicular to the face veneer; usually consists of narrower pieces of veneer.

Cup - distortion of a board characterized by dishing or deviation from flatness crosswise.

Defect - any irregularity in or on wood that may affect or limit its suitability for a particular end use.
   a. Sound defect - any defect presenting an essentially sound surface such as tight knots, stains, and pitch seams or pockets.
   b. Open defect - any defect creating a void or interruption of a solid surface, such as knotholes, insect holes, wane edge, and machine gouge.

Density - mass per unit volume, usually expressed as pounds per cubic foot; see also, "specific gravity."

Equalization treatment - controlled conditions applied in a dry kiln to bring lumber to a nearly uniform moisture content.

Equilibrium moisture content (EMC) - the moisture content at which wood reaches a balance with moisture conditions of the surrounding atmosphere, as determined by relative humidity and temperature.

Grain - the general direction of the fibers in wood or lumber.
   a. Cross grain - grain deviating in direction from the longitudinal axis of the piece of lumber.
   b. Short or end grain - terms applied to cross grain deviating sharply from the longitudinal axis of the piece; often irregular or swirled, as around knots.

Green-clipping - clipping green veneer to rough panel widths, or to narrower widths as necessary to remove inadmissible defects.

Heartwood - wood extending from pith to the sapwood, usually darker in color and with lower moisture content than sapwood.

Insect (borer) holes - oval, circular, or irregular holes in wood caused by larvae and adult insects.

Jointing - rendering the face or edge of a board perfectly straight and flat by passing it across a fixed cutter head.

Kerf - the cut made by a saw.

Knot - the part of a branch that has become incorporated into the trunk of a tree.
   a. Intergrown knot - that portion of a live branch which is firmly embedded in the trunk; a tight knot.
   b. Encased knot - that portion of a limb overgrown by the trunk after the branch dies; usually a loose knot.

Kraft overlay paper - a paper made from softwood neutral sulphate pulp, to which 20 percent by weight phenolic resin has been added; particularly noted for its strength.

Modulus of elasticity - a measure of the stiffness or rigidity of a member or material; i.e., resistance to deflection.

Modulus of rupture - a measure of the load, slowly applied, that a member or material will support for a short time.

Moisture content - the quantity of water in wood, expressed as percentage of the weight of the ovendry wood.

Parchmentized overlay paper - purified wood-pulp paper treated by sulphuric acid or other chemicals to produce a hard, tough, water- and abrasion-resistant paper.

Particle board - an engineered panel product made from dry wood particles that have been coated with binder, formed, and hot pressed.

Patches, veneer - sound wooden plugs inserted in veneers to replace defective areas such as knotholes.

Pitch pocket or seam - an opening along the grain, often between two annual rings, containing pitch or resin.

Roundup - trimming irregularities and natural taper from a veneer bolt to obtain a right cylinder, preparatory to cutting usable veneer.

Sapwood - outer portion of a woody stem, extending from bark to heartwood, usually lighter in color and with higher moisture content than heartwood.

Scribner Decimal C log rule - a diagram-derived log rule designed to estimate the board-foot content of logs to the nearest 10 board feet.

Shelling - a separation of springwood and summerwood occurring during the manufacture of veneer, leaving a rough surface and irregular thickness; may be associated with excessive pressure bar compression or wide-ringed woods.

Shrinkage - contraction of wood caused by drying below fiber saturation point.

Sliced veneer - veneer cut from a flitch by a slicing machine rather than a rotary lathe.

Specific gravity - density or weight of wood per unit volume, expressed as a decimal proportion of the weight of an equal volume of water.

Stain - discoloration of wood caused by outside agents; common causes are the oxidation of extractives in the wood, and the growth of mold-like fungi in the wood.

Stress at proportional limit - stress in the extreme fibers of a member, at the limit at which deformation begins to occur at a rate greater than proportional to added load.

Sunken glue joint - depression along or adjacent to a glue line caused by further shrinkage of the wood about the glue line after final surfacing.

Telegraphing - a tendency of some furniture-core particle boards to transmit surface particle patterns or irregularities through face veneers; often referred to as "show-through."

Tension failure - failure of wood fibers in tension, or on the side of the member opposite the load.

Touch-sanding - a sizing operation consisting of sanding lightly to a specified panel thickness.

Twist - distortion of a board about its longitudinal axis, placing the corners in dissimilar planes.

Veneer - thin layers or sheets of wood cut from a log or flitch by a rotary lathe, slicer, or saw.

a. Tight side - the upper surface of the veneer sheet as it is cut; i.e., the surface opposite the lathe knife, and hence free of knife checks.
b. Loose side - the lower or inner surface of the veneer as it is cut; i.e., the surface adjacent to the lathe knife, exhibiting knife checks.

Vulcanized fiber - an unsized, unloaded sheet material made by treating cotton rag-base paper with a zinc chloride solution.

Wane - the presence of bark, or lack of wood, along the edge or corner of a board.

Warp - variation of a board or panel from a straight or true plane, including cup, bow, crook, and twist.

Barger, Roland L., and Fleischer, Herbert O.
1964. New products from low-grade ponderosa pine timber. U. S. Forest Serv. Res. Paper RM-10, 54 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Demonstrates the technical feasibility of producing types of plywood, particle board, overlaid siding, laminated beams, and laminated flooring. Products and manufacturing procedures either circumvent or tolerate the range of defect common in low-grade ponderosa pine sawtimber.

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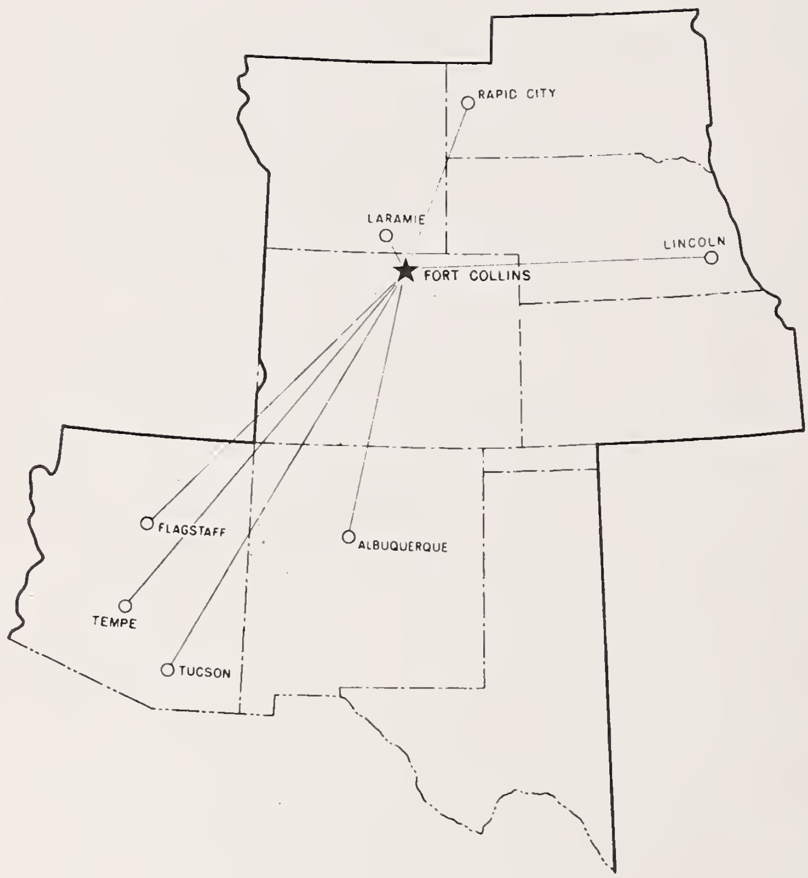
RAPID CITY
LARAMIE
LINCOLN
FORT COLLINS
FLAGSTAFF
ALBUQUERQUE
TEMPE
TUCSON